EXPERT SYSTEMS IN HEALTH FOR DEVELOPING COUNTRIES

PRACTICE, PROBLEMS, AND POTENTIAL

DAYO FORSTER

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Expert Systems in Health for Developing Countries

Practice, Problems, and Potential

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PREFACE

Over the last few years on several occasions, the International Development Research Centre has been requested to fund the development of expert systems for the diagnosis and treatment of human diseases in developing countries. The plausible argument was advanced that such systems would make scarce medical expertise much more widely available, and thus be of great assistance in countries where few medical practitioners were found. However, the Centre was cautious about supporting work in this area, especially in view of the very limited use to which expert systems for medical diagnosis have been put in industrialized countries.

In order to provide the background information to help the Centre orientate its programs in this area, and also to give researchers in developing countries an up-to-date perspective on the field, this report was commissioned by the Information Sciences and the Health Sciences Divisions. It consists of a state-of-the art review of the status of expert systems applied to human health, with emphasis on priority areas for developing countries, and was carried out using literature research and personal contacts. The author, Dr. Dayo Forster had just completed research on the effectiveness of medical expert systems in Africa. Her conclusions justify a cautious approach to the use of expert systems in medical diagnosis in developing countries, but at the same time point out other areas of promise for their application to human health care.

This appears to be the first publication to review and compare experience in this field and as such provides a solid base for further research. IDRC hopes that a wide dissemination of this report will help increase the effectiveness of health research in developing countries.

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SUMMARY

This report aims to investigate what role expert systems may usefully and effectively play in health in developing countries. To set the scene, the introductory section outlines some priorities of health in developing countries. The issues listed are based on suggestions in the literature, as well as discussions and correspondence with medical practitioners working in developing countries.

To date, much interest has been directed towards possible applications for computer-assisted diagnosis, and the report focuses on these. The third section briefly discusses historical trends in industrialised countries, and some of the reasons why there are few systems in routine, widespread use. Despite limited successes at implementing medical expert systems in industrialised countries, some believe that research into diagnostic systems for developing countries should be pursued. The design and structure of fifteen systems are summarised. The discussion that follows tries to assess why it is unlikely that those systems designed specifically for diagnostic support at the primary care level will have any immediate prospects for practical implementation.

Based largely on the earlier list of health priorities, alternative, and possibly more viable, opportunities for applying expert systems techniques are proposed. These include medical diagnostic aids in research in very specific domains, but it is recommended that the focus should move from support systems for delivering health services to those that give support for managing health delivery.

Two appendices are included - an annotated bibliography covering background material as well as references of direct relevance to this subject area; and a list of contacts, researchers who have worked in the areas of (medical and other) expert systems or computer applications in developing countries.

PRIORITIES OF HEALTH IN DEVELOPING COUNTRIES

The Alma Ata conference helped to refocus attention on health as a priority for national development strategies. The resulting Health for All by Year 2000 strategy stresses the need to provide primary health care, redirecting resources towards rural, community-oriented health delivery rather than the widespread hospital-based approach [World Health Organisation, 1978]. Since then, many governments claim to have adopted this strategy [Hill, 1987], and progress has been made in some countries [Gowers, 1987; Heggenhougen, 1987]. Enormous problems still remain however, due not only to a lack of financial and human resources [see figures in World Bank, 1990], but also to a lack of efficient means of using available resources for maximum benefit [World Bank, 1989]. It has been pointed out that the largest contributor to improved health is increased wealth; that poor health is a characteristic of poverty [Stevenson, 1987; World Bank, 1990]. This principle applies both at a national and at the community level. The health service must compete with other sectors for financial resources, and is dependent on the size of the national budget and a country's economic wealth. Illiteracy is linked to poverty [World Bank, 1990], and many disadvantaged communities lack the necessary skills and information needed to make their own health choices, change habits that encourage the spread of disease, or campaign for their health needs.

In the short term, it is unlikely that the economies of developing countries will improve sufficiently to benefit the most disadvantaged groups. Meanwhile, what should be done to reduce the impact of poverty-induced disease and illness? One positive action is to exploit available resources for maximum productivity. This might lead us to question, for example, the wisdom of a 50 million naira (= US$7 million) appeal for a kidney centre in Nigeria [quoted in Korpela, 1990a]. Instead, there must be a search for alternative and more effective means of improving the health status of a larger proportion of communities living in poverty. Listed below are some pressing problems that surely deserve prior consideration. They are based on a variety of sources: bibliographic references, discussions and correspondence with medical practitioners working in a developing country context.

1. Health information for planning and management

> "... many health organisations have felt the need to prioritise health problems and interventions more carefully, based mainly on documented need, and to target PHC services to those with the greatest need, ...". [Wilson et al., 1988]

Many health facilities routinely collect patient statistics on attendance, disease and treatment [World Health Organisation, 1987; Kulakow, 1983; Wilson et al., 1988]. This requirement may be an additional burden on health providers at the primary care level, distracting from normal duties [Reitmaier et al., 1987]. The quality of the data collected varies, and the data that is processed by the district health office is therefore potentially unreliable. There is an imbalance in the energy of resources expended in data collection and compilation, and their ultimate use in planning and routine management.

Available resources need to be targeted to areas of greatest need, and agencies need to be able to respond to new health problems as they arise, before they escalate to an epidemic scale. There must be a change in awareness of the role that accurate, up-to-date data can play in health management. The set of data items collected should be reduced to a bare minimum. The administrative burden may need to be abolished altogether, replaced by well-directed periodic surveys that will give a more reliable picture of the situation. Often cited [Wilson et al., 1988; World Health Organisation, 1987] is the need for the staff who process the data to see what it is used for, and thus gain an understanding of the value of doing their jobs well. To achieve this, the data collected has to be presented in an easily understood format, and then percolated down through to the regional and community levels.

The value of accurate and reliable information is demonstrated by the Information Management Systems at PCEA Chogoria Hospital in Kenya. One area of application is the community health department data on child welfare (immunisation and growth monitoring), family planning services, and antenatal care at rural clinics [Fischbacher, 1988]. Before the computerisation process began, the manual system was reviewed and improved. Now the benefits are obvious: data is released on time to government and donor bodies; there is less of an administrative burden on clinic nurses; defaulters on antenatal, immunisation and family planning can be followed up within a month; there is better co-ordination between clinic and hospital services, and discharged patients who are still at risk can be followed up within the community; there is rapid feedback to clinics about their performance.

2. **Preventive health care**

"There are both social and economic arguments for concentrating efforts on the prevention of disease, as being far more cost-effective than the treatment of individual sufferers. Where, as in the tropics, communicable diseases constitute the main medical problem, their incidence is not materially affected by hospital services, whereas campaigns to prevent disease can often dramatically reduce morbidity and mortality." [Stevenson, 1987].

Budgetary allocations still tend to be unnecessarily biased towards curative care. Undue emphasis has often been put on the provision of drugs, which may consume up to 60% of the total health budget of a dispensary [Evans et al., 1981; Danish Medical Bulletin, 1984; Helling-Borda, 1983]. In some communities, this has created an expectation for pharmaceutical treatment when health officers are consulted, and a lack of credibility in their abilities if their drug dispenser roles are not fulfilled.

Many of the cases that present at health care units suffer from preventable communicable diseases [Stevenson, 1987; Elliott, 1985]. Focus should therefore change from curing those cases that finally succumb to disease as a result of high transmission levels, to a policy of preventing as many disease occurrences as possible. The role of health units must be seen differently, their preventive aspect must be stressed and made known to communities. The community health worker's role must involve an explicit mix of preventive duties, with less emphasis on curative aspects. This should include community education, hygiene and nutrition advice, immunisation, and monitoring of maternal health.

In The Gambia, bednets are used by a majority of the population, but are largely ineffective against the onslaught of malaria. When treated with insecticide, however, they have been shown to decrease the incidence of malaria morbidity significantly [Snow, personal communication]. Even more recently, further work has shown that their use decreases overall mortality by approximately 70%.

3. **Fertility and population control**

"The demographic and ecological implications of public health measures must be understood at all levels, especially by the community. If these are desustaining (sustainability reducing), complementary ecologically sustaining measures, especially family planning and ecological support, must be introduced with them." [King, M, 1990].

Whereas King concentrates on the currently fashionable theme of ecological destruction by an ever-expanding population in a finite world [see also Harrison, 1990], he does highlight the need to recognise and implement a double-edged policy - family planning measures to be coupled with means for reducing mortality rates.

With falling mortality levels due to many basic improvements in medical knowledge, but no immediate corresponding fall in fertility levels to act as a counter-balance, many developing countries are experiencing rapid population growth. Uncontrolled population expansion has been blamed for the inability of many governments in the developing world to continue to provide basic services for its nationals. High population growth rates put pressure on publicly provided facilities. High fertility can damage the health of both mother and child, as the mother's poor health affects the child's health at birth and in the critical first years of life [World Bank, 1990].

If resource levels do not increase in real-terms as populations grow, the quality of health care that can be provided will fall. "Providing family planning services is one of the most effective policies for better health" [World Bank, 1990]. Studies have shown that although some women may not want any more children, family planning services may not reach them [World Bank, 1990]. It is vital that family planning services are provided and promoted at the same time as techniques for improving child survival rates.

In Thailand, a very effective family planning programme has been implemented, using the media, economic incentives and community involvement to increase the use of contraception. The practical benefits of reduced fertility have been stressed, and the message delivered using a mix of occasions: carnivals, fairs, weddings, to break taboos surrounding birth control. In 1985, about 60% of all couples practised some form of birth control [World Bank, 1990].

4. **Training and support of health professionals**

"For many developing countries, the most realistic solution for attaining total population coverage with essential health care is to employ community health workers who can be trained in a short time to perform specific tasks." [World Health Organisation, 1978].

An absolutely basic requirement of an effective health service is a committed cadre of personnel, who are well-trained and valued. Health personnel may be unwilling to work in remote, rural areas with limited access to utilities. These postings may prove to be doubly unattractive if workers feel they are unvalued, unsupported, and little remunerated (financially or career-wise).

There is a scarcity of health staff at all levels, but the focus must be on staff who can work at the community level [World Health Organisation, 1978]. It is important that a large amount of staff training takes place in locations close to their communities of origin. Ongoing training, supervision, and a prompt supply of consumables all help to keep morale high.

The Zimbabwean Ministry of Health has produced through ZEDAP (Zimbabwe Essential Drugs Action Programme), a series of booklets on various aspects of primary health care. The initiative was in response to a survey which showed that many primary care units had little literature available, and that staff wished to upgrade their skills in a variety of areas. Titles were based on suggestions made during the survey. For each module, the consultant expert's first draft is tested and reviewed by a panel before circulation of the booklet [ZEDAP, 1987].

There have been few applications of computer technology for the pursuit of these goals (Association Internationale Futuribles, 1985], but many suggestions of its utility [Board of Science and Technology for International Development, 1986; 1988; World Health Organisation, 1988]. Expert systems for medical diagnosis, in particular, have aroused much interest, and the rest of this report deals with this topic.

The development and trends of this field of research within industrialised countries is summarised in the next section, the application of expert systems to developing countries is discussed in detail in a later section. As well as documenting research to date, this report shall try to question whether research preoccupations are adequately focused on the health priorities in developing countries discussed above, and what alternative applications may be of benefit.

EXPERT SYSTEMS IN MEDICINE

The expert system application that seems to have generated most attention is the use of diagnostic support systems. This section briefly overviews the history of computer-assisted medical decision-making in industrialised countries and some recent trends. Some of the reasons proposed for the development and use of medical expert systems are outlined, and the mismatch between promised benefits and current practice discussed.

Brief history

The 1970s are the landmark decade for research into artificial intelligence techniques for medical applications [Lindberg, 1987; Kulikowski, 1987]. This period was preceded by some 15 years of work on conventional statistical means for computer- aided diagnosis. Bayesian inference, Boolean logic, classical hypothesis testing, and pattern recognition methods had all been explored by the end of the 1960s. Researchers pointed out the need for symbolic, and not only numerical, ways of manipulating knowledge, and coined the term "expert system" to embody the concept of what they were trying to achieve - an acceptable level of expert-like behaviour by computer programs.

Four major systems were developed by 1975, each famous for different expert system techniques - PIP (use of frames), CASNET (use of causal association network), MYCIN (use of rules) and INTERNIST (handling of multiple problems) [Clancey and Shortliffe, 1984]. They were not all necessarily directed at solving serious practical applications, MYCIN for example was purely an experimental research model [Shortliffe, personal communication]. The developers, as well as researching into ways of representing and manipulating medical knowledge, were often also interested in formalising heuristic knowledge. Since then, research efforts have spawned a number of new systems and knowledge representation methods.

In recent years, there have been several trends in the paths research projects have pursued: a move towards systems for general practice, expert system shells, and tutoring systems. Of the four early systems, INTERNIST was designed for the most general domain area - internal medicine. This was an exception, as the majority of research efforts have remained in strict, narrow domains (see the MEDINFO series, and the Lecture Notes in Medical Informatics series). Recently, some attention has turned towards microcomputer based systems that can be used by generalists. For example, knowledge from INTERNIST is the basis of QMR (Quick Medical Reference) [Bankowitz et al., 1989], and a project has started on a general Oxford System of Medicine (OSM) [Fox et al., 1987].

The second popular trend has been the conversion of systems to expert system shells by removing the knowledge and leaving a system of inference that could be made to work on any similarly represented knowledge. Because of their origin, these have tended to restrict knowledge representation to only one method. A number of shells have been built specifically for rapid prototyping of expert systems. The simpler versions of these can be used by less experienced users, although they offer only a limited range of techniques [Land et al., 1988]. Richer and more complex environments will generally require a technical specialist for knowledge engineering [Alberta Research Council, 1990].

Finally, the conversion of systems into tutoring aids; a number of systems have had computer-assisted instruction spinoffs. Intelligent tutoring systems are a natural extension of diagnostic systems, and probably present one of the most likely products from expert systems. "In fact, an expert system has a natural instructional potential insofar as it has the ability to assess a situation and produce an expert recommendation or conclusion. In association with the ability to justify or explain its outcomes, the system has all the components needed to compose a student's assessment with its own and instruct the student as to what the appropriate conclusion should have been." [Alberta Research Council, 1990] The disadvantage of the narrow focus of expert systems under diagnostic circumstances becomes a positive advantage when used to teach a student in a compartmentalised fashion.

Practice versus promises

Several reasons have been put forward as the motivation for building expert systems [Buchanan and Duda, 1983; Alberta Research Council, 1990; Clancey and Shortliffe, 1984a; Basden, 1983]. First, to replicate expertise and prevent loss of knowledge, allowing geographical dispersion of expert level advice. Second, as documentation, to structure and codify knowledge, make heuristic rules explicit and provide a reference source. Third, for immediate availability of consistent medical advice, regardless of fatigue, mood, or stress, with a shorter response time. Within some domain areas, e.g. machine diagnostics, systems have been built that allow these expectations to become reality. Examples of such systems include R1, PROSPECTOR, and IBM DEFT.

However, there are few medical expert systems in routine use outside their development environments. Immediate benefits have generally not been associated with even the most optimistic of these development efforts. Shortliffe [1984] reports that PUFF, EXPERT and ONCOCIN have been developed to the point of being used by physicians; more recent reviews add HELP, CARE, QMR, DXPLAIN to that list [Rauch-Hindin, 1985; Shortliffe, 1987; Alberta Research Council, 1990].

There has often been heated debate about the possibility of encoding expertise into computer systems [Dreyfus and Dreyfus, 1986]. To help resolve this conflict, the role of systems needs to be defined more thoroughly [Shortliffe and Clancey, 1984]. Realistic researchers do not envisage a computer-based system as a replacement for human experts [Shortliffe and Clancey, 1984]. Instead, systems are often proposed as a source of advice, as warning or monitoring systems, or as critiquing systems. Despite these less threatening roles, it is still difficult to get medical expert systems used routinely. Why is this?

Various reasons have been put forward as explanations [Fox, 1984; Clancey and Shortliffe, 1984a; Shortliffe, 1981]. Systems have to be shown to be:

(1) Demonstrably needed - there must be a demonstrated and recognised need for the system, not just a desire to research into an interesting problem. If the system allows users to take on new functions and enhance their productivity, there is a greater chance that it will be used.

(2) Usable - systems need better interfaces, improved response time, explanation facilities, and an awareness of limits.

(3) Accountable - the ultimate responsibility for taking decisions must lie with the user, who must have the ability to query and overrule the system's recommendation.

(4) Reliable - the system has to be shown to give consistently expert recommendations in thorough evaluatory trials.

(5) Affordable - cost still proves to be a major barrier, as it involves not just purchase costs, but also running costs.

(6) Maintainable - the system's knowledge base will need updating as scientific knowledge expands.

To quote at length from Shortliffe [1990] on the future of medical expert systems in industrialised countries:

> "The future of clinical decision-support systems inherently depends on progress in developing useful programs and in reducing logistical barriers to implementation. Although ubiquitous computer-based aids that routinely assist physicians in most aspects of clinical practice are still the

stuff of science fiction, progress has been real and the potential remains inspiring. Early predictions about the effects such innovations will have on medical education and practice have not yet come to pass, but growing successes support an optimistic view of what technology will eventually do to assist practitioners with processing of complex data and knowledge. .... we have learned much about what is not likely to happen. The more investigators understand the complex and changing nature of medical knowledge, the more clear it becomes that trained practitioners will always be required as elements in a cooperative relationship between physician and computer-based decision tool."

Progress has been, and will continue to be, slow before expert diagnostic systems can begin to be useful. Why then have expert systems for diagnosis been suggested for developing countries? What systems have been built and have they fulfilled initial research expectations? These questions are considered next.

MEDICAL EXPERT SYSTEMS FOR DEVELOPING COUNTRIES

It has been suggested that applying medical expert systems to developing countries will be easier than in industrialised ones. This is attributed to the lack of trained medical specialists, which will make diagnostic support systems even more valuable in practice [Board of Science and Technology for International Development, 1986]. An alternative explanation is that the proposed enduser is different, and therefore the diagnostic problem is simpler. Paramedical workers in developing countries are less knowledgeable about medicine, are limited in clinical observation skills and in the number of drugs available and the number of tests that can be performed. Consequently, the domain area is restricted, limiting the scope of the knowledge base to the number of diseases that can be differentiated and treated [Goldberger and Schwenn, 1983].

Based on this initial premise, the case for developing decision-support tools at the primary health care level has been expressed as follows. There is a shortage of personnel [Briggs, c1986, Byass, 1988] in rural communities [Goldberger and Schwenn, 1983; King and Beck, 1990; Auvert et al., 1986]. Many of the staff left to cope are not physicians [King and Beck, 1990] and have limited access to medical expertise and continuing education [Auvert et al., 1986], are poorly equipped and supported [Porenta et al., 1988], yet have a large number of patients to attend to [Goldberger and Schwenn, 1983; King and Beck, 1990]. If their skills could be augmented, then they could successfully treat a larger number of patients, relieving the burden on the higher levels of the health care system [Uplekar et al., 1988]. Thus, a source of knowledge that can be instantly accessed will provide continuous diagnostic support [Centre Mondial, c1984].

This section reviews several attempts that have been made at providing medical decision-support tools for clinical workers in developing countries. The system outlines include more established projects, as well as those with just one main working paper. This span gives some indication of the strength of interest, and effort already expended in this area. Many researchers are seemingly unaware of the work of others, and few authors quote more than a small selection of the other systems mentioned below. Consequently, some research is unnecessarily duplicated, because project results are not widely published and disseminated.

Aegerter, Auvert and others

CONSULT-EAO

INSERM, Paris, France; Medicins sans Frontieres, Paris, France.
[Aegerter et al., 1987; Aegerter et al., 1989].

1. Content
   Diagnostic knowledge base extracted from the TROPICAID system (see below).
2. Structure
   As for TROPICAID (see below).
3. Inference
   A patient case is generated by randomly selecting a diagnosis. All the findings of the knowledge base are assigned a value. Depending on the level of difficulty of the case, the system may assign a more or less faithful representation of a disease, or it may include conditional findings that trigger other diseases. The expert module's solution of the problem is then used to assess the student's performance. The student's requests for information are assessed for validity, with the system intervening only when the student makes a mistake.
4. Interface
   Intended for computer-aided instruction of rural health workers, providing individualised, self-paced learning. How the user enters information is not specified. The system outputs a critique of the student's diagnostic procedure. Where the student differs from what the expert module would have chosen, the discrepancies are listed.

5. Development and delivery environment
   Development environment not specified. Can be used on any IBM PC-compatible.
6. Evaluation
   Evaluation will be performed in schools for health workers.

Auvert, Aegerter and others
TROPICAID-2
INSERM, Paris, France; Medicins sans Frontieres, Paris, France.
[Auvert et al., 1985; Auvert et al., 1986ab].

1. Content
   The current version now covers 500 diagnoses, 350 basic symptoms, 2000 clinical signs, and 160 essential drugs.
2. Structure
   Stored in frames. For each sign in the database, there is a corresponding question (classified in one of several different categories to reflect the capabilities of the user). All the signs are linked into a network to preserve consistency.
3. Inference
   The system begins by selecting suspected diseases, based on the patient symptoms entered. The diagnoses selected are ordered and the most pertinent question is chosen. The answers update the findings base and allow some reordering, possibly the elimination of some diagnoses, the confirmation of some beyond the certainty threshold, or the addition of new ones. This question-reorder cycle is continued until a stop criterion is satisfied.
4. Interface
   It was intended as a tool for rural health workers to increase their effectiveness, and to act as a teaching aid. Successive selection grids are used to record symptoms. This takes on average 30 seconds. The system outputs diagnoses with various levels of certainty. For those which are certain, specific treatment is suggested; for those diseases which are highly probable, the specific treatment is recommended unless there is a common generalised treatment which can be used instead.
5. Development and delivery environment
   Developed on a Victor S1 microcomputer using Pascal-UCSD, under the Softech P-system. The delivery machine is a BLAISE handheld computer, with an 8x40 character screen, weighing 1.5kg.
6. Evaluation
   The earlier version, TROPICAID-1, which based its knowledge on the Essex diagnostic flowcharts, has been evaluated to some extent. The knowledge was represented differently, and the current version was revised as a result of an informal evaluation of this first version. Information items were stored as records in a packed thesaurus like file, with a separate index file. The fixed tree pathways were represented as nodes, each node containing the code number of the questions to ask, and for each possible answer, the code number of the next node, or the code of a diagnosis. The authors assessment included the following comments: flowcharts are rigidly structured; the system produces diagnoses for diseases that cannot be treated; the decision-making process does not really correspond to real-life; no explanation can be offered because of the knowledge base structure; knowledge is often duplicated. The system was also tested by some paramedics in Chad. TROPICAID-2 has been tested for several months in Kinshasa, Zaire, in three studies to investigate ease of use, quality of the systems decision and utility of the system. The results show that TROPICAID-2 was easy to learn to use; that it makes too many hypotheses but focuses and prescribes well; that it improves the therapeutic decisions of nurses in terms of cost and efficacy [Aegerter, personal communication]. The results will be published soon.

Boyom Sop
{EXPERT SYSTEM ON ENDEMIC TROPICAL DISEASES}
Faculte des Sciences, Labo. Informatique, Yaounde, Cameroun.
[Boyom Sop, 1990].

1. Content
   The current prototype is limited to malaria, covering six types of malaria infection.
2. Structure
   Knowledge is represented in a row and column format.
3. Inference
   Method not specified.
4. Interface
   It was intended to be a source of knowledge for generalist doctors, and for medical students, on the diagnosis of some of the major tropical endemic diseases: malaria, trypanosomiasis, filariasis, leprosy, bilharzia, and leishmaniasis. The system prompts with a series of menu choices, or questions requiring yes or no answers. The system outputs a patient summary, and a diagnosis, or a statement that the patient's disease is beyond the scope of the system.
5. Development and delivery environment
   It was developed in Turbo Prolog on the IBM PC compatible, and runs on any IBM PC compatible.
6. Evaluation
   The system is at the development stage.

Briggs, Javett and others
SASEP (Sign And Symptom Evaluation Program)
Ammad Medical Systems, Randburg, South Africa.
[Briggs et al., c.1986].

1. Content
   The article claims that the system contains "dozens of knowledge bases which represent subsets of medicine", but nothing else is specified.
2. Structure
   Knowledge represented as production rules.
3. Inference
   Rule-based system, with probabilities assigned to hypotheses. If certain conditions are met, then a set of actions are to be performed or a particular hypothesis is to be tested. The system reiteratively performs these processes until a diagnosis becomes true falling within suitable confidence limits, or no conclusion can be reached.
4. Interface
   The system was meant to provide diagnostic and therapeutic decision support at primary health care centres, to be used by registered nurses with some additional training. One major presenting symptom or sign is selected on a touch sensitive terminal. The keyboard is not used, and all further input consists of touching YES or NO alternatives in response to a question generated by the system. If the disease falls within the treatable category, another expert system CATT (Computerised Aid To Treatment) is accessed, which prescribes therapy - drug, dosage and duration - based on cost and effectiveness.
5. Development and delivery environment
   The development environment is unspecified. The Hewlett Packard touchscreen computer is used as the delivery machine (King and Beck, 1990).
6. Evaluation
   Piloted at an outpatients department of a provincial hospital, where it was used by trained registered nurses and compared against peers and medical practitioners.

Byass and Corrah

{PROBABILISTIC DECISION-MAKING SYSTEM}

Medical Research Council Labs, Fajara, The Gambia.

[Byass, 1988; Byass and Corrah, 1989].

1. Content
   Indicators for the database were selected from details entered on a questionnaire prepared for an outpatient screening clinic. The system contains general patient data on sex and age, the season of the year, 40 signs and symptoms, and 27 management strategies.
2. Structure
   Database.
3. Inference
   Based on Bayes' theorem, using the unmodified probabilities of indicators in repeated calculations of advisabilities of the various strategies. When a certain threshold level of a strategy is exceeded, the strategy is recommended.
4. Interface
   The system was developed to give diagnostic support at rural health care delivery units. An appropriate user interface needs to be developed. The system's outcome is a treatment strategy.
5. Development and delivery environment
   The development environment is unspecified, but the delivery machine is the Spectrum ZX88 laptop computer, powered on a solar battery.
6. Evaluation
   The system was tested using information collected from random consultations at an outpatient clinic. 500 cases were randomly selected from those used to build the database and used to check for internal consistency. Another 500 cases were selected from the additional unused case histories. Both sets were run through the system and the outcomes compared, and matched on whether the strategies proposed were in the same group. From the internal cases, the computer gave the equivalent management in 74% of cases. It could be said that the computer performed tolerably well in 88% of cases, as it incorrectly diagnosed only 12% of potentially life-threatening cases. On further analysis of these life-threatening cases by another clinician, he agreed with the computer on 41% of cases, and with the outpatient clinic diagnoses on a third of cases; for the remaining cases, all three management strategies were different. The overall concordance level achieved, and the number of potentially life-threatening cases were slightly higher for the external cases.

Eamsiri, Malasit and others

MEDICAL TUTOR

Kasetsart University, Bangkok, Thailand; Sirijaj Hospital, Bangkok, Thailand.

[Eamsiri et al., 1987].

1. Content
   Knowledge about the various causes of anaemia.
2. Structure
   Semantic network and scripts.
3. Inference
   The expertise part deals with problem-generating and answer-evaluation. The student model contains information about the student's understanding and reasoning. When choices are selected, the number of strong criteria is counted to evaluate the student's understanding. The tutoring strategy is the part that interfaces between the expertise part and the student.
4. Interface
   It was developed as an instruction tool for medical students in the differential diagnosis of anaemia. During a session, the system critiques the user's requests for information. If the student's final diagnosis is wrong, the system disproves it and gives general information related to the selected choices.

5. Development and delivery environment
   It was developed in Turbo Prolog, on an unspecified machine.
6. Evaluation
   A group of 20 medical students each spent 10-20 minutes for a lesson, with "encouraging" results. The students were interested but complained the lesson was too short.

Flikeid, Mackintosh and Cook
{CLINICAL MICROCOMPUTER SOFTWARE}
National Capitol Systems, Virginia, USA; Medical Logic International, South Carolina, USA.
[Flikeid et al., 1986].

1. Content
   Three demonstration diagnostic treatment modules have been written, to cover intestinal, respiratory and skin complaints.
2. Structure
   Not specified.
3. Inference
   Not specified.
4. Interface
   The decision-support system is part of a set of software developed for mid-level practitioners at the dispensary and clinic level. Data is entered using function keys to respond to YES/NO questions about the presence of symptoms. As output, the system gives a diagnosis and prescription, plus suggestions about further tests for confirmation of the diagnosis, and a listing of diseases with similar symptoms.
5. Development and delivery environment
   The system was developed in GWBASIC on an IBM compatible computer, and can be implemented on any IBM compatible computer.
6. Evaluation
   Not done.

Forster
ESTROPID (Expert System for TROPical Diseases)
London School of Economics, London, England.
[Forster, 1987; Doukidis and Forster, 1990a; Forster, 1990b].

1. Content
   Covering the set of 64 flowcharts developed by Essex [Essex, 1980], to include about 190 diseases and conditions.
2. Structure
   In lists. Each chart is represented in two ways: a nested list structure containing the question texts with unique question identifiers, and as a function representing the flowchart dynamics.
3. Inference
   Given a set of symptoms to start with, the system evaluates the keywords and decides on an order of access to the charts in the knowledge base. It confirms the heading of a chart, uses the appropriate decision function, accesses any other functions indicated (but keeping track of those accessed so no circular path is followed) until it reaches a diagnosis.
4. Interface
   The system was meant to support paramedical staff in the diagnosis of many common diseases presented at their clinics. The user interface is based around the use of a keyboard, allowing text entry, numeric options from a menu list, and Y/N answers. The system commences operation by requesting basic information about a patient. Then a series of menus, based around the broad groupings used by Essex, prompts for the presenting symptoms. In some cases the symptoms are

not in the menu lists and the text entry facility is used to type out symptoms in simple English. If the set of words used is not matched directly in the knowledge base, the system then proceeds in an interrogatory fashion, to ask all the questions in its knowledge base that contain the keywords of the user entry. If none of these are confirmed, the user is informed that the entry is not understood. The system pronounces at least one diagnosis and a recommendation of where the patient should be treated.

5. Development and delivery environment
   It was developed in muLISP on an IBM PC XT, and can be implemented on any IBM compatible computer.
6. Evaluation
   In a trial in an outpatient department of a district hospital (in November 1989), 200 patients were seen by a clinical officer first, and then a doctor. Half of the clinical officer's consultations were seen using ESTROPID. The computer increased the time the clinical officer spent with patients, and increased the number of symptoms elicited from the patient at the beginning of a consultation (demonstrating a checklist effect). The scale of disagreement per patient was 24% between CO and doctor when the computer was used, and 14% under normal practice. This was a small study and the limited statistical data collected on concordance levels between the different types of consultations are not necessarily generalisable. What was more interesting were the additional observations of normal clinical practice, and the CO's assessment of the system's worth. The tentative conclusion of this trial is that preliminary base-line studies need to be conducted before the effect of a decision support tool can be investigated. Health personnel may need help, but their need of computerised decision-aid technology is questionable, perhaps manual paper-based means may be adequate.
7. Notes
   Being the developer as well as the critic for this system, I must add a personal note. On discussion with several other researchers in this area, with emerging interests in the application of medical expert systems in developing countries, I have come to realise that they initially approach the problem in the same way I did - with enthusiasm, and an optimistic outlook (see two earlier writings, 1987 and 1990a, both written in 1987). By the completion of my doctoral programme, optimistic enthusiasm had changed to a more realistic pragmatism, see 1990b.

Goldberger, Schwenn, and others

MEDIT-MEDIC

Centre Mondial, Paris, France.

[Centre Mondial, c.1984; Goldberger et al., 1983; Goldberger and Schwenn, 1983; Hurtado and Newman, 1986].

1. Content
   MEDIC covers 200 diagnoses, over 400 signs or symptoms and about 1500 decision nodes.
2. Structure
   The knowledge in MEDIC is represented in a decision diagram, related to flowcharts, supplemented by production rules with probability values.
3. Inference
   MEDIC traverses decision nodes with small sets of production rules attached to determine the direction of flow at each branch point.
4. Interface
   MEDIC was developed to provide computer-assisted diagnostic and therapeutic decision-making at the primary care level, as well as monitoring of the patient's progress. User input features are unspecified. MEDIC's output is diagnostic and therapeutic advice, or suggested changes in management for patients who do not improve. MEDIT was to provide a means for a doctor to use a graphic interface to prepare or edit reasoning structures of the expert module. The user interface is graphical, operated with a mouse.

5. Development and delivery environment
   MEDIC was written in C on a DEC-20 and the VAX, and runs on a Husky Hunter portable. MEDIT was developed on a LISP machine and has been adapted to run on the IBM PC.
6. Evaluation
   Preliminary tests (in April 1984) resulted in a better understanding of reactions to the system's methodology, and a list of software changes to be made. Other tests were to be carried out in 1985, but no literature has been unearthed about these results.
7. Notes
   This system was the precursor of the TROPICAID system; and some researchers involved in this project also went on to start the TROPICAID one [Aegerter, personal communication].

Kastner, Ostroff and others
PECM (Primary Eye Care Model)
Rutgers University, New Brunswick, USA.
[Kastner et al., 1984; Ostroff et al., 1985; Ostroff et al., 1986].

1. Content
   WHO guidelines for health workers on how to deal with eye problems are used as the source of knowledge. The system covers 72 observations or findings, 39 diagnostic categories, 15 different treatments or actions and contains 131 reasoning rules.
2. Structure
   Knowledge is represented in three parts: (1) the hypotheses, which may include intermediate conclusions, (2) the findings, grouped into numerical, yes/no, checklist and multiple choice questions, and (3) the rules, which may be finding- to-hypothesis ones containing a list of findings each with a test value, and a hypothesis with an associated confidence weight; or hypothesis-to-hypothesis rules.
3. Inference
   Rule based inference.
4. Interface
   The system was developed to assist primary health workers in the management of common and potentially blinding eye disorders. The user enters Y/N to questions or selects an option from a menu list. The system outputs a case summary, followed by diagnostic conclusions and management recommendations.
5. Development and delivery environment
   The development was done using the EXPERT reasoning model (an expert system shell) on the DEC-20. The software is translated automatically to run in BASIC on the enduser computer system. It can run on a number of machines: IBM PC compatibles, Apple IIe and EPSON HX-20 handheld computers.
6. Evaluation
   Tested in the U.S., using a number of hypothetical cases, then with some real cases recorded at a U.S. health centre. A hundred cases recorded at a primary health care site in Yemen were then used, and a number of improvements made as a result of this test. There are plans to evaluate the systems further by public health nurses and primary physicians in Tunisia and in Egypt.

King
{PROGRAM FOR STD DIAGNOSIS}
University of Edinburgh, Edinburgh, Scotland.
[King, K, 1990].

1. Content
   Sexually transmitted diseases as covered in the ZEDAP (Zimbabwe Essential Drugs Action Programme) manual.

2. Structure
   The basic system (computerised STD manual) has different cards: disease, clinical features, management, drug, drug dosage for diseases, contraindications, and index cards. For the diagnosis component, diseases were subcategorised under main presenting symptoms, and a grid was made of diseases and their associated symptoms.
3. Inference
   Various cards in the basic system can be accessed entirely haphazardly by pressing buttons for additional information required. The diagnostic module uses Yes or No buttons for the presence or absence of a disease.
4. Interface
   It has a graphical interface, with buttons that can be pointed to with a mouse and selected. The diagnostic component produces a diagnosis and a treatment recommendation.
5. Development and delivery environment
   It was developed and is implemented in Hypercard on the Apple Macintosh.
6. Evaluation
   Volunteers in the department of AI used the basic system (i.e. without the diagnostic capability) at their leisure. Responses to the system were favourable. Comments included: the linearity of the system in some sections, some ambiguous buttons, inconsistency of button design. King concludes that Hypercard is probably most appropriate for display purposes, especially in exploiting the strength of its interface for any knowledge representation architecture.
7. Notes
   It was developed as a prototype system to investigate the possibility of using hypercard to present medical knowledge; the diagnostic flowchart capability was added on later.

Moon and Lo

ROPES (Rule-based Out-Patient Expert System)

Chinese University of Hong Kong, Hong Kong.

[Moon and Lo, 1988]

1. Content
   Flowcharts from Essex were used, supplemented by information recorded on knowledge acquisition forms after interviews with doctors. The system includes 195 diseases, 305 signs and symptoms, 53 flowcharts for the forward reasoning process, and 285 production rules for its backward reasoning process.
2. Structure
   Flowcharts are represented as rules. All decision-box questions belonging to the same manifestation are grouped together. The probabilistic reasoning system also uses rules, but supplemented by certainty factors for symptoms.
3. Inference
   The categorical reasoning system traverses the flowcharts based on answers to questions in the decision box. A set of diseases are suggested as possible. The probabilistic reasoning system divides a goal (i.e. confirmation of a disease) into subgoals. If a subgoal cannot be verified directly, it is further subdivided until certainty factors can be obtained. In this way, each disease suggested from the forward-chaining process is tested.
4. Interface
   It is intended as a tool for physicians working in outpatient departments. It operates in a multi-window environment with on-line help and explanation facilities.
5. Development and delivery environment
   All coding, except that for the interface was done using an expert system programming tool called OPS5, developed by DEC. The interface was programmed in PASCAL as it supports better input/output facilities. ROPES will run on a DEC VT 220 terminal connected to a VAX 11/780 system.

6. Evaluation
   Informal assessments by the developers point out the specificity of the Essex flowcharts, which were designed for East Africa, and the need for their revision for the Asia. The system also needs to be converted to run on an IBM PC, and the software need to be adapted to use Chinese medical terms instead of English ones. The system will then need to be field tested.

Porenta, Pfahringer and others
{DECISION-SUPPORT SYSTEM FOR VILLAGE HEALTH WORKERS}
Austrian Research Institute for Artificial Intelligence, Vienna, Austria.
[Porenta et al., 1988].

1. Content
   Combines several sources, textbook knowledge from two well-known medical authors supplemented by the experience of a doctor who worked for a short while in northern Ethiopia, and statistics collected on presenting symptoms of patients seen at an ambulatory care centre over 3 weeks. The system covers diarrhoea, infestation with worms, diseases affecting the eyes and skin, and several kinds of infectious diseases.
2. Structure
   The different disease groups are represented in at least two different ways. For diarrhoea and worm infestation diseases, an expanded decision network is used. Each contains nodes, with rules on how to proceed to the next node, represented as frames. Each frame then has various slots with attributes flagging the presence or absence of a symptom. In addition, a rule based approach is used for skin and eye diseases. Each symptom has 2 certainty factors between 1 and -1, the first indicating evidence in strength of a disease and the evidence against a disease. It is not specified how common infectious diseases are represented. Therapies are also represented as frames.
3. Inference
   All nodes in the network branch to other nodes based on whether the response to a node question is yes or no. At each node, an interpreter evaluates and weighs a set of symptoms included in a rule and determines which branch to pursue. With the rule-based strategy, a set of diseases that are potential candidates for diagnosis are chosen. These are ranked and worked on sequentially by the system, certainty scores being calculated for the disease under consideration by combining the factors using an algorithm. Reordering continues, and the procedure stops when a certainty threshold is exceeded. To suggest treatment, the system uses contraindications, side effects, treatment of choice and price information to decide on an adequate scheme.
4. Interface
   The aim of the system was to support village health workers in the diagnosis of common diseases in developing countries, including tutorial features for reference. There are three entry points to the system (diagnosis, therapy, and drug prescription). In the diagnosis mode, a menu-based system is used for the entry of patient symptoms. All subsequent questions asked by the system require yes or no answers. The system produces a diagnosis, treatment plan, and detailed advice about drug prescription if necessary.
5. Development and delivery environment
   It was developed on an IBM PC compatible using VIE-KET, a hybrid knowledge engineering tool that offers a range of different representation schemes and languages (IQLISP was used), running under MS-DOS. It runs on any IBM PC compatible.
6. Evaluation
   An informal style evaluation was done, and several points noted. (1) There is an assumption of familiarity with medical terms, so that a smart dictionary might be needed. (2) There is a need for investigating language-independant interfaces. (3) The method of question and answer is rigidly structured and may require more flexibility. No field tests have been conducted.
7. Notes
   This system was demonstrated in Edinburgh. It is extremely basic, and its coverage of diseases using presumably complicated AI techniques seems largely unnecessary. Although it might be excused the interface, being a prototype system, it has numerous other obvious (after a five minute

demonstration) deficiencies. To illustrate, it uses diarrhoea as an initial symptom to arrive at a treatment recommendation of "treat with ORS".

Uplekar et al

SYMPMED 1

The Foundation for Research in Community Health, Bombay, India.
[Uplekar et al., 1988].

1. Content
   Using outpatient notes maintained by village health workers, 24 common symptoms were identified. To treat the diseases causing these, 25 drugs are included in the program from the WHO list of Essential Drugs.
2. Structure
   Algorithms for each symptom.
3. Inference
   Algorithmic?
4. Interface
   The system was developed to help paramedical workers to filter through patients who need to see a doctor, and prescribe for those patients with simple, common ailments. The user enters one major symptom in answer to a question on what bothers the patient most. If other symptoms are present and are not included in lower levels of the symptom algorithm, they should be entered later in the consultation. The system suggests either a prescription, or recommends referral to a doctor.
5. Development and delivery environment
   It was developed on an IBM PC using dBase III, and also runs on an IBM PC compatible.
6. Evaluation
   SYMPMED I was tested in an urban dispensary on 900 cases over 12 years old, approximately half of whom were seen by a medical assistant, the rest by a non-medical person, an engineer. All patients were seen first by a user on the computer and then seen by a general practitioner. The computer printouts and the doctors' notes were then compared. Results show that the computer's diagnoses "generally" matched the physician's (78%), and the non- clinical person (69%). In assessing their system, the authors say that (1) Suggesting treatment based on symptoms without clinical examination or investigation is against medical principles, but that their approach is justified in producing what the patient requires - therapy; (2) The interface may need to be translated, taking into account different medical expressions; (3) The knowledge base has to be refined, before a larger field test can be conducted.

Xie, Guan and others

(TRADITIONAL DIAGNOSIS OF LIVER-RELATED DISEASES)

Hospital of Traditional Chinese Medicine, Beijing, China.
[Ambros-Ingerson et al., 1987; Hurtado and Newman, 1986; Xinsong et al.,1983].

1. Content
   The expertise of a leading traditional practitioner, a septagenarian, was encoded was posterity. Hundreds of symptoms are coded for each ailment, as well as the names of numerous herbs used to treat each disease.
2. Structure
   Database.
3. Inference
   Rules, including the use of mathematical methods and fuzzy logic.
4. Interface
   The system was meant to be used by apprentice practitioners. The user enters 10-12 symptoms, which take about 5-6 minutes to identify and log. The system takes about a minute to process the

data and produce a printout. A Chinese traditional medical prescription (containing about 10 ingredients in varying amounts) is produced as output.

5. Development and delivery environment
   Language used for development not specified, but implemented on the VAX-11/750.
6. Evaluation
   Program is now in its sixth edition, and is reported to have an 80% cure rate.
7. Notes
   Other systems developed in China are mentioned in the Hurtado and Newman article, covering dermatosis, orthopaedic ailments, rheumatism; Xinsong et al also mentions hepatitis, general diagnosis, gynaecology and nephritis.

There have been some anecdotal reports of other systems developed in Brazil, Cameroun, China, Cuba, India, Malaysia and Thailand, but no further documentation has been obtained on any of these systems. Doubtless, there are others that have reached the prototype stage and are not reported here. It is the author's wish that this pool of bibliographic material on medical decision-support for developing countries should be expanded further, to cover existing systems more comprehensively. Researchers are urged to send copies of reports of their own work, or the work of others not reported here.

Discussion

What are the general characteristics of these systems? What similarities and differences exist in the way they were designed? What suggestions are made by researchers as to their future role? What trends do the evaluation results report?

The majority of systems are designed for paramedical workers, only three indicate otherwise (Boyom Sop for medical students and physicians; Moon for physicians; Xie for apprentice traditional doctors). It seems to be widely accepted by the researchers quoted in the preceding section that the health workers who need most support work at the rural level and that they lack adequate diagnostic capabilities. Both of these premises hold true, but present only a small part of the problems encountered in providing health services at the community level. A whole host of factors may contribute to, or explain the problem of inadequate health service delivery. The health workers may be insufficiently trained and are therefore unable to perform their role, they may be poorly paid and consequently badly motivated, they may not be provided with an adequate supply of drugs and the problem may lie in their limited therapeutic range rather than an inability to diagnose illnesses, they may be putting a wrong emphasis on curative care rather than preventative care. Each of these factors and probably many others, change the way the initial presentation of the problem can be interpreted.

There are many alternative solutions, and computer-assisted diagnostic support may be the most expensive and least useful of them all. An understanding of the role and environment in which health workers work can be glimpsed through Heggenhougen et al., 1987, which examines what Tanzanian community health workers do in practice. Their findings do not correspond with the simplified view of the problem presented by many researchers who suggest that computerised aids would be useful for health workers at this level. Their study focused on community health workers, but it is likely that, for many developing countries, more highly trained health paramedics such as nurses operate within similar environmental and operational constraints.

Most of the systems are for a wide spectrum of diseases except for Boyom Sop (malaria, to be extended to six major tropical diseases), Eamsiri (anaemia), Kastner (eye diseases) and Xie (liver-related diseases). The number of diseases or conditions that can be distinguished vary from 8 (Boyom Sop) to 500 (Auvert). Boyom Sop's system is a prototype, so can be excused its small number of diseases. However, Uplekar's system covers such a small subset of diseases that the use of a computerised medium may be questioned. Many systems also include drug prescription (Aegerter, Auvert, Briggs, Byass, Flikeid, King, Porenta, Uplekar and Xie), and some of these bypass diagnosis altogether.

A most appropriate alternative for channelling research effort, and one suggested by many researchers, would be training. For most health workers, the range of diseases to be covered would be quite wide. Few developing countries have extensive facilities for the treatment of very specific ailments like cancer. Within contexts with such specialised facilities, for example in China, expert systems for small domain areas of medicine might also find a training role. If systems are to evolve from diagnostic support to training, as Auvert and Aegerter have done, it seems that general rather than specific systems should continue to predominate.

Many developers often quote learning as an additional byproduct that will be evident after a system's continual use. It is however difficult to see how a user can learn from a complicated system that proceeds from the first step of symptom history to the last step of therapeutic prescription with all of its logic enclosed in a black box. If the system is simple enough to have very fixed and easily recognisable paths from history to advice after being used a few times, why bother to use a computerised system at all? Why not use a manual one, which would make the path more explicit and usable? If medical expert systems are to be adapted for training, they must cover an area with sufficient complexity to make it worthwhile. To be truly beneficial as a tutoring system, the steps between symptom history and therapy recommendation must be transparent and open to critique and examination by the user.

A surprising number of developers have used the Essex flowcharts (Auvert, Forster, Goldberger, Moon), or have referred to them (Byass, King, Uplekar). Essex seems an obvious starting option for many as it is a single source of information on general medicine for developing countries. As a binary tree structure, it is amenable to rule-based reasoning, a methodology favoured by many of the researchers. From the information available, only two have used a database approach (Byass and Boyom Sop). Some developers use more than one reasoning technique, but in Porenta's system, the mix of techniques used seems overly complex for the purposes for which it was designed.

The preponderance of various micros as a delivery machine mirrors the general feeling that they are the most portable way of distributing computer technology. The choice is firmly biased to IBM compatibility as a standard. This would yield the option to install a variety of applications packages to perform other functions on the same computer. Non-IBM machines such as the Spectrum ZX80 offer cheaper alternatives, but restricted access to other off-the-shelf packages. Cost, function and future use are all considerations to be taken into account when choosing a hardware environment for developing countries.

Some of the systems described in this section are prototypes, a few explicitly built to test the suitability of a method for application to a wider domain (Boyom Sop, Flikeid, King). The rest have stopped at various stages of development, and only one is claimed to be in routine use (Xie). Most systems seem to have been evaluated only at the "laboratory stage" [Wyatt and Spiegelhalter, 1990] using informal methods. A minority of systems have been subjected to formal evaluations that include quantitative data (Auvert, Byass, Forster, Kastner (?), Uplekar, Xie). The methodologies used in Kastner and Xie are unclear, but a common technique used for the remaining four is the matching of the computer's diagnosis with that of a health professional. Byass uses peer review to judge amongst the discordant cases, Forster uses peer review to try to judge the scale of discordance for all cases included in the study. Auvert and Aegerter also use peer review, but work with a group of experts. For Byass and Uplekar, the system's outcome was treatment, and comparisons were made based on treatment groups rather than specific medication. By reducing the number of groups that must be compared, the probability of the computer being correct simply by chance is increased, [see discussion in Gaschnig et al, 1983]. Most expert system developers remain optimistic about the potential of their systems after some form of evaluation, whether informal or formal.

This discussion section has attempted to uncover similarities and differences between the specific systems described earlier. Could systems like these be put into use effectively? The next focuses on the problems of implementing medical expert systems in general - why is it so difficult to get them to work in real life?

IMPLEMENTING MEDICAL EXPERT SYSTEMS FOR DEVELOPING COUNTRIES

The issues that constrain widespread acceptability and use of medical expert systems in industrialised countries are also important for implementations in developing countries, constraining the viability of many of the systems presented above. There are certainly very striking differences between the industrialised and developing countries with regard to the issues mentioned below. The differences within the developing group of countries should also not be forgotten (Bangladesh is very different from Brazil, for example). What may be totally inappropriate in one may not be such a bad suggestion in another. The medical infrastructure and resources available will differ between developing countries and should be borne in mind when considering the issues below.

1. Problem identification

Researchers in developing countries may not get to know about new or emerging technologies until after some considerable delay. It is therefore likely that many ideas will come from outside a developing country, as foreign researchers see different areas with application potential. However, to develop any system beyond a prototype, the full co- operation of developing country expertise should be sought. One of the most crippling deficiencies of attempts at medical diagnostic-aids is that many emerge from ideas of presumed benefits to health professionals rather than a thorough appraisal of the need for such support. This is true in both developing and industrialised countries. However, the consequences of poor contextual understanding are much harder to bear in resource restrained developing countries. The process of health service delivery is often not well understood, neither are the conditions under which paramedical workers have to work.

A staffing problem should not necessarily be resolved with less skilled persons armed with a magical computer. Problems of rapid turnover of staff may be due to dissatisfaction rather than training. Should these problems then not be solved with better personnel management? How would computer-assisted diagnosis encourage job satisfaction if other infrastructural requirements (a sturdy health building, mechanisms for support, continuing training and so on) are not provided? Many researchers do not have an adequate grasp of the health situation and needs of developing countries, and consequently offer systems for trivialised contexts.

The difficulties of providing adequate health services and the problems health workers face need to be appreciated, the range of solutions available investigated and the pros and cons of each option weighed. A prerequisite is an accurate assessment of the existing problem within an organisation, to design systems more likely to fit in with the organisation's most pressing needs. The solution may not be full computerisation. It may mean a reorganisation of a manual procedure, or partial computerisation (with or without an incremental, add-on approach).

2. Interface design

Another problem for implementation has been the relative lack of attention to user interface development. Familiarity with the concept of computers can be increasingly assumed in industrialised countries, but exposure to computers in developing countries is often limited or nonexistent.

To successfully apply expert systems for novice computer users in developing countries, good design incorporating new graphical interface techniques and input/output devices can help to improve the ease of use of the system. It is important to realise that icon based interfaces have a high imported cultural content, and the symbols may need to be adapted to suit cultural interpretations. Design should also allow for the mode in which the system is to be used. Often in industrialised countries, systems are meant to be used in hospitals, and consulted for management advice on inpatients. If the patient is more likely to be seen only once and has to be managed there

and then, the implications are different. To reduce patient discomfort, the length of a consultation must remain within a reasonable range.

More emphasis should be placed on the user's role in the development of a suitable interface during the evolution of a system. A potential stumbling block in trying to apply the user participative approach to developing countries is that users without any previous exposure to computers will not know what to expect from a system. Therefore, their value in the early stages of system design is limited. If a prototype approach to system development is made explicit, users could instead be made to work with a prototype, on whose performance they can base their suggestions.

3. **Accountability**

There is also the question of who is responsible for the decisions made by the system. If used by unskilled staff who cannot question its outcomes because they do not understand the underlying health implications, will the blame for any faulty reasoning therefore lie with the system designer? What must not happen is a sense in which the computer itself is regarded by the user as responsible for the decisions it gives. There has been resistance in industrialised countries because users fear that the computer would gradually take over the functions of humans. For the moment, this type of reaction has not been noted (or much studied) amongst users in developing countries, but it seems less important, perhaps because a science fiction vision of computers taking over control of society does not generally exist as strongly as it does in the industrialised world.

Whatever the case, the user must understand the basic reasoning of the system and be given the ultimate responsibility to challenge its output. Only in strictly defined domains is it possible to construct a complete knowledge base which covers all possible inputs. Health expertise is not so well defined, and common sense considerations have to be taken into account during consultation. If the burden of accountability lies with the system builder, the user must be skilled enough to question the assumptions, logic and outcomes of the system.

4. **Evaluation**

Too often in the past, researchers have labelled ad hoc attempts as evaluation, undermining its value as a means of judging a system's worth. A structured approach to evaluation can uncover and challenge hidden assumptions in the expected role, or the design, of a system. A formal evaluation process must be incorporated into the development life cycle and not simply regarded as a final, but disposable stage. Evaluation must demonstrate not only the ability of a system to diagnose with acceptable levels of expertise, but also the ease with which it fits into the consultation process, and its overall contribution to improving health care.

Out of the huge number of systems built in industrialised countries, some have undergone thorough assessment of diagnostic ability and a few have considered reasons for resisting the introduction of diagnostic-aid systems. Few of the systems for developing countries can claim to have been broadly evaluated, partly because the projects are still in their infancy. To be embraced by health professionals at all levels, their impact on improving patient management must be proven.

5. **Cost**

The cost of computers is falling as rapid advances are made in hardware design, so that fast processors and massive storage devices have become the norm for PCs. For general practitioners, it has become not only invaluable for managing their medical practices, but also feasible to do so. For developing countries, however, the cost of hardware for systems at the primary care level remains prohibitively high. Given the size of the budgets of many health centres, and their treatment capabilities, the initial purchase cost seems disproportionately large and can hardly be justified. If many health facilities cannot afford to buy a refrigerator to store vaccines, why should a

computer be bought to diagnose diseases that could have been prevented if the vaccines had been viable in the first place? Costs of computer equipment may be rapidly decreasing, but they have not yet fallen to the stage of being within the reach of the average developing country health unit budget.

6. **Maintenance**

Knowledge in a field like medicine does not remain static; new methods of control, scientific information, drugs, diagnostic procedures are continually becoming available. Unless the system can be regularly updated to include this new information, it will rapidly become obsolete. If system developers leave after the inception of the project, this ongoing support needs to be provided from somewhere within the health system. Industrialised countries have a large pool of computer specialists and doctors working in this field from which research projects can obtain replacement expertise. Developing countries do not, and the likelihood of a knowledge engineer being available, who understands the system's operation from both the medical and computing viewpoints, is small.

Developing countries have many examples of high technology projects that have ground to a halt because of the lack of seemingly straightforward replacement items. A capability to maintain the computers in rural, maybe remote, areas will be necessary. When considered against the backdrop of current distribution facilities within the health system, where drugs are not delivered on time, there is little possibility that this will work in reality. Not only will there be a lack of repair facilities, but there remains also the possibility of loss of equipment by other means: breakage, or theft.

Discussion

Of course, attempts can be made to overcome some of these problems in one way or another. The difficulties of diagnosing at the primary care level could be investigated in more detail. More effort could be made to involve users in the system development process. Systems could be evaluated more thoroughly and rigorously before they are used. Their contribution to overall health care delivery could be studied. Recurring costs could be reduced by considering items such as solar panels to supply power. Nationals could be trained as knowledge engineers during the inception of a project, and then left to continue its evolution. Similarly, staff could be trained to identify computer problems and maintain them. But to what end? And at what cost?

One objection to the continued effort towards developing computer-based diagnostic aids for the primary care level is about whether this is the way to solve the diagnostic problem. To quote from Shortliffe et al., 1984:

> "It is also always appropriate to ask whether computer-based approaches are needed at all for a given decision-making task. For all but the most complex clinical algorithms, for example, the developers have tended to discar computer programs."

Some researchers, on deciding that there is a problem, have developed alternative manual methods for decision-support for developing countries [Essex, 1980; Fountain, 1982]. The Spiegelhalter-Knill Jones clinical scoring system is an example of a manual risk assessment method, which reduces a decision-making problem in a complex medical environment to simple manual arithmetic manipulation with reference to tables [Seymour et al., 1990].

Another objection is about whether the real problem has been elicited in the first place. A problem of diagnosis probably does exist at the primary health care level, but the scale and impact of the problems has not been thoroughly investigated and documented. Workers may instead have a greater need for improved support for other activities, prompt drug supplies or continuing training. King, K, [1990] has rightly included a preliminary investigation in her proposal for a feasibility study of medical diagnostic-

aid systems. The problems discussed above indicate that there are serious difficulties in ensuring viable and sustainable long-term use of medical diagnostic-aid systems at the primary health care level. If the lack of diagnostic support is discovered to be significantly jeopardising the lives of patients, manual rather than computerised decision-support methods seem to be the better way to meet the need at this level.

An argument against the use of medical diagnostic-aid systems for routine use at the primary health care level can be structured around three statements. Cost is prohibitive (initial purchase, and running costs); sustainability is unlikely (theft, maintenance); and accountability must be shared (between developers and users). If the system is used by skilled workers, the benefits of a computerised medium over a manual one using ongoing training is minimal; it may possibly be detrimental to the standard of health care delivered. When considered in terms of alternative uses of the financial resources, the allocation seems particularly inappropriate within the context of existing health priorities.

Paramedical workers at the community level need support; the scale of the health problems in developing countries makes that clear. Their role is much more than to present curative care, and the other aspects (family planning, preventive health care, community education, and so on) need to be emphasised. Computer-based support for the health system only seems viable at the higher echelons of the health structure - the regional (co-ordinated) level, where their benefits can be shared amongst a range of applications. If computer resources are concentrated at this level, backup computer systems could be a feasible option. Maintenance facilities are probably more accessible from regional centres than far- flung primary care villages. These, and other conditions for smooth computing, can be more easily met under intense, well- maintained research or planning centres.

The coordination of data collection, planning of population control measures, training, supervision of preventive health care policies would then be possible at the regional level. Expert system techniques are not necessarily irrelevant to the needs of developing countries, but their application to ordinary day to day tasks is best considered at the regional and central levels of administration. Some alternative possibilities are discussed in the next section.

FURTHER OPPORTUNITIES FOR RESEARCH

Looking at the problems of health in developing countries in a wider context reveals a number of other exciting, and challenging areas for application. Examples of such application areas would include the use of systems in training, support for administration tasks, including the maintenance of patient records, and logistics planning and management. Systems for some of these seemingly ordinary tasks do exist, but with added "intelligence", they become easier to use, and enhance productivity.

Used in conjunction with other new and emerging technologies, the scope and diversity of expert system applications can be extended even further. For example, the use of graphical interfaces, alternative input devices, voice output, hypertext and multimedia applications, offer interesting ways of developing user interfaces, geared more sensitively to end users.

1. **Medical diagnostic-aids in research**

   Systems with very specific domains might be useful in contexts other than primary care. For example, Professor Barry Jones (retired opthalmologist, personal communication) has quoted the use of microcomputers to record data collected by opthalmologists during a national eye health survey in Morocco. This research oriented context, in which computers are used in the field, may offer an opportunity for using an expert system to critique the diagnoses made, using the observations recorded by the opthalmologist.

   Another possibility is for screening a large number of patients, again in a research setting, as a way of rapidly assessing the extent of a growing health problem. For example, a system could be used to select those patients who seem at most risk of suffering from HIV/AIDS, for examination by a consultant expert.

   Of course, the suitability of either of these type of systems depends on the need for accurate information, and the potential value would need to be balanced against the effort necessary to build, test and update the system.

2. **Data collection and processing**

   This area seems to be one of the most amenable and easily computerisable [Wilson et al., 1988; Chapman, 1987; ElKholy and Mandil, 1983]. It is important that data, if it is to be collected at all, should be gathered in a reliable manner. There are opportunities for applications in routine statistics, not only in the production of tables, but also perhaps for support in the use of analytical statistical techniques and tests. As with current trends in PC computing, software should be graphically based (a bonus for users in developing countries not previously exposed to computers.) There is also some potential in survey management, and in the production of maps for use in censuses or as sampling frames. Geographic information systems and all they entail (mapping technology, databases, data gathering) could be enhanced by expert system techniques and should be amongst the priorities. Placed in the hands of a national health team, equipped with the ability to summarize the health status of the population in a spatial manner, and to pinpoint hot spots and problem areas around the country, they offer a powerful tool for improving management.

3. **Operational research and planning**

   OR techniques seem very applicable to the common problems such as scheduling and distribution in this context [Deer and Lauria, 1985; Chapman, 1987; El Kholy and Mandil, 1983]. Central or regional management has to deal with the distribution of supplies, and work out the logistics of how to do it efficiently. Alternative planning scenarios could be simulated to explore the impact of different levels of resource allocation. These techniques could equally be applied to emergency management, to improve response to famine, disasters, and refugee rehabilitation [Kohli, 1986].

Microcomputer supported decision models have also been suggested for disease control in the community [BOSTID, 1988]. It has also been proposed for epidemiological models that could be used in public health data analysis and planning [Working group, 1983].

4. **Intelligent tutoring systems**

The conversion of diagnostic systems into tutoring systems seems a most appropriate use of current expertise [Aegerter et al., 1989; Chapman, 1987]. However, the central role of purely diagnostic teaching must be displaced by the need to teach about the mechanisms of disease, their cause, method of spread, and ways of control. Simple diagnostic procedures are not out of place, but need to link in with knowledge on how to prevent the illness in the first place. A combination of graphics and voice may be a very effective means of reinforcing more conventional teaching. The difficulty of maintainability does remain with this approach, and there is a need for systems that can be updated by teachers as new knowledge and procedures emerge.

5. **Information storage and retrieval**

Access to overseas databases will probably remain prohibitively expensive, especially for access to commercial databases. If cheaper links by satellite and free database access do become possible, long distance information retrieval will become a more attractive prospect. There are systems like ENVIRON, a bibliographic computer database of literature on environmental side-effects of pesticides in the tropics [The Courier, 1989], compiled in Europe that can be accessed free of charge. Organisations like Satellife have offered subsidised communications facilities by satellite to some institutions working in developing countries [Behrens, personal communication]. In the interim, technologies like CD-ROM (compact disk - read only memory) offer an alternative means of circulating pooled information.

Locally compiled and managed information may also be structured for database entry. The challenge is to develop interfaces that can conduct searches in a more intelligent manner than many of the inscrutable ones currently available. Easy to use systems which provide the required information using good search algorithms will be quicker to gain widespread use.

Current medical diagnostic research projects have generally not been oriented towards health priorities in developing countries. The techniques for building such systems remain of value, and may be applied to other areas, including those suggested above. Their usefulness in these alternative application areas is not guaranteed, and developmental work will need to proceed carefully. A thorough preliminary investigation, a good choice of development tools, a prototypical approach to system development, and an integrated approach to evaluation will all help considerably. Projects with more realistic aims and approaches to systems development will stand a better chance of success. It is hoped that this report will help to stimulate more concern for the design of viable and effective systems.

APPENDIX A

ANNOTATED BIBLIOGRAPHY

This bibliography covers a range of topics which are directly or indirectly related to the application of medical expert systems in developing countries. Articles on health and development, the problems and priorities of health, the use of computers and the problems of computerisation in developing countries, medical expert system applications in industrialised countries, expert system applications in fields other than health in developing countries, and methods of evaluating expert systems are all included.

ALBERTA RESEARCH COUNCIL, [1990], Medical expert systems, Department of National Defense Contract, DSS No.52SS. W8477-8-SC07, Advanced Technologies Department, Alberta Research Council.

A commissioned report, separated into 6 tasks. The first is a literature review of artificial intelligence and expert systems, landmark expert systems in medicine, civilian and military systems developed. Task 2 reports on trends, listing the criteria for success of a system, general trends in techniques, hardware and software, and emerging technologies. Task 3 reviews the Canadian Forces Medical Services operations, gives details of some site visits and an analysis of areas of potential benefit. Task 4 identifies technical areas of exploration, to provide assistance in primary care and evacuation decisions, as well as for computer-based training. Tasks 5 and 6 contain details of a meeting of the expert panel, and a summary.

AEGERTER, P., AUVERT, B., GILBOS, V., DESVE, G., ADRIAN, V., LANDRE, M.F. & BOS, D., [1989], An intelligent tutoring system designed for rural health workers in developing countries, in: Barber, B., Cao, D., Qin, D. & Wagner, G. (eds.), Medinfo 89, North- Holland, 953 - 956.

Describes a computer-assisted instruction system, CONSULT-EAO, developed to supplement the training of rural health workers. This system is derived from an earlier diagnostic system TROPICAID, providing the basic diagnostic module covering some 400 diseases and 1500 signs. The other parts of the system are the patient case generator, a student model, and a pedagogical module to interface between the expert system and the student. Simulation begins by presenting the patient's chief complaints; during the session, data is provided to the user as requested, if judged to be appropriate; the student's diagnostic conclusion is then checked and faults corrected. The current system is limited to disease diagnosis and will be extended to cover therapy.

AEGERTER, P., AUVERT, B., GILBOS, V., DESVE, G., BENILLOUCHE, E., LANDRE, M.F. & BOS, D., [1987], A computer-assisted instruction system designed for rural health workers in developing countries, in: Proceedings of Medical Informatics Europe 87, Rome, 1341 - 1348.

Very similar to Aegerter et al., 1989.

AGBALAJOBI, F., [1980], The unstructured approach to medical computing in Nigeria, in: Kaihara & Lindberg (eds.), Medinfo 80, North- Holland, 656 - 659.

This paper assesses the potential of computer applications in hospital-based health care delivery in Nigeria. It first gives a brief summary of the history of the health care system, and the current state of computerisation within it. The author sees possibilities for implementation in health care planning, medical research, laboratory services and patient administration. He stresses the need for defining priorities to increase the chances of successful implementations.

AGBALAJOBI, F., [1983], Indigenisation of health informatics through adaptation, in: Fernandez Perez de Talens, A.F.P., Molino, E. & Shires, D. (eds.), Health informatics in developing countries: Experiences and viewpoints, North-Holland, 173 - 180.

The author discusses the growing need for computer-based information systems in health care delivery, and some of the resource deficiencies that make implementation difficult. It describes briefly the socio-economic conditions of developing countries in Africa. It discusses some of the possible approaches to implementing computerised systems: integrated or modular approaches, and suggests one possible stepwise development procedure which attempts to make systems fit naturally into the environments in which they are to be used.

AMBROS-INGERSON, J., AZARMI, N., DELGADO-RANNAURO, SA. & WOBCKE, W., [1987], Artificial intelligence in the third world, M.Sc. project, Department of Computer Science, University of Essex.

This student report attempts to present the current role of AI in the third world and its possible future role. Some alternative scenarios of third world response to AI research, development and use are considered.

ANGELIDES, M.C., [1990], Intelligent tutoring systems, Course lecture notes in Intelligent Knowledge Based Systems, at the Department of Information Systems, London School of Economics.

The author reviews the rationale behind computer-assisted learning systems and describes the historical development of the field. Some ideal characteristics of intelligent tutoring systems are listed and the main components of such a system described. Various proposals on design architecture are summarised and some examples of systems given. The author concludes with an assessment of future research needs and potential.

ASSOCIATION INTERNATIONALE FUTURIBLES, [1985], Quelle informatique pour quel developpement? Bilan d'une analyse documentaire sur l'informatique dans les pays en developpement, Rapport de l'Association Internationale Futuribles, Paris.

Report from the first phase of a project to investigate how information technology can contribute to solving some of the problems in developing countries, the conditions for optimum utilisation, and the direct and indirect effects of its use. The introductory section defines the concepts "third world" and "development" and presents seven sectors where IT could be applied. Traditional focus has been on public administration, but opportunities also exist in health, nutrition, education, communications, primary industry, and the management of development. The problems of adapting emerging technologies to these areas are discussed.

AUVERT, B., GILBOS, V., AEGERTER, P. DU, L.T.H., BOUTIN, P., PHILIPPE, A.M., BENILLOUCHE, E., VAN LOOK, F. & EMMANUELLI, E., [1985a], An expert system as an aid to decision-making by para-medical personnel in developing countries, in: van Bemmel, J.H., Gremy, F. & Zvarova, J. (eds.), Medical decision making: Diagnostic strategies and expert systems, Elsevier (North- Holland), 81 - 84.

See Auvert et al, 1986a for a similar, but updated presentation.

AUVERT, B., BENILLOUCHE, E., AEGERTER, P., DIQUET, B., BOUTIN, P. & MONIER, J.L., [1985b], A drug information system for general practitioners using a hand-held computer, in: van Bemmel, J.H., Gremy, F. & Zvarova, J. (eds.), Medical decision making: Diagnostic strategies and expert systems, Elsevier (North- Holland), 129 - 132.

Describes the therapeutic knowledge base used by the TROPICAID system, which can be accessed separately under the PHARMAID system. The drug data base covers 500 most-used drugs, and includes pharmacological information, treatment dosage and contraindications.

AUVERT, B., AEGERTER, P., GILBOS, V., BENILLOUCHE, E., BOUTIN, P., DESVE, G., LANDRE, M.F. & BOS, D., [1986a], TROPICAID: A portable expert system for medical decision-aid in developing countries, in: Salamon, R., Blum, B., & Jorgensen, M. (eds.), Medinfo 86, North-Holland, 222 - 224.

The rationale behind the development of an expert system for diagnosis for treatment advice (TROPICAID) for use at the primary health care level is explained. The components and structure of the system (frame-based databases on drugs and diseases), its inferencing methodology and operation are described. Preliminary testing in Chad, and the expected role for the system is discussed in the conclusion.

AUVERT, B., AEGERTER, P., VAN LOOK, F., DU, L.T.H., BOUTIN, P., MONIER, J.L., EMMANUELLI, X., GILBOS, V. & BENILLOUCHE, E., [1986b], A hand-held decision-aid system designed for rural health workers, Computers and Biomedical Research, 19, 80 - 89.

Contains the same basic information as Auvert et al., 1986a, with some additional information on the development environment, a discussion of the evaluation of the first prototype TROPICAID-1, and a sample session.

AUVERT, B., AEGERTER, P., GILBOS, V., BENILLOUCHE, E., BOUTIN, P., DESVE, G., LANDRE, M.F. & BOS, D., [1986c], Has the time come for a medical expert system to go down in the bullring: The TROPICAID experiment, in: Trappl, R. (ed.), Cybernetics and Systems 86, Reidel Publishing Company, 727 - 734.

See Auvert et al, 1986a for a similar discussion.

BAARK, E., [1986], Global trends and implications for developing countries - Constraints and options for the development of new information technologies, Bulletin of the Advance Technology Alert System No 3, Centre for Science and Technology for Development, June 1986, 136 - 140.

The author discusses some constraints on the utilisation of information technology: infrastructural bottlenecks (power, telecommunications, and maintenance), the organisational context (often informal, lacking standardised data), economic and technical constraints (costs, software development capability, running costs, market size). He considers the scope of policy making, and proposes a framework within which policy choices can be made.

BALACHANDRAN, C.S., FISHER, P.F., & STANLEY, M.A., [1989], An expert system approach to rural development: A prototype (TIHSO), The Journal of Developing Areas, No 23, 259 - 270.

The problem of desertification provides the application area focus for this paper. Using an expert system shell, 27 rules were designed to estimate the degree of land degradation, given some user information. The authors discuss the testing and evaluation procedures they intend to use, after further development of the current prototype. A lengthy appendix describes a sample session.

BANKOWITZ, R.A., MCNEIL, M.A., CHALLINOR, S.M., PARKER, R.C., KAPOOR, W.N. & MILLER, R.A., [1989], A computer-assisted medical diagnostic consultation service - Implementation and prospective evaluation of a prototype, Annals of Internal Medicine, 110, 824 - 832.

A brief history of the development of QMR (Quick Medical Reference), for use by academic general internists, is given. This is an experimental micro-computer based decision-support system, based on the knowledge base of INTERNIST. Thirty- one patients defined as posing a diagnostic challenge were chosen to test the accuracy of the system. Consultants gathered and input the data, and a ward team assessed the value of the system's suggestion. The patients were also followed up until a definitive diagnosis was established. The diagnostic sensitivity of the computer was close to that of the consultants, but better than that of the ward teams. In the majority of cases, the computer recommendations influenced the postconsultation diagnoses of the ward team, and was judged to be of educational value by house officers.

BASDEN, A., [1983], On the application of expert systems, International Journal of Man-Machine Studies, 19, 461 - 477.

The author concentrates on the application of expert systems to real-life problems. He discusses some advantages of the expert systems approach, their potential roles, benefits, and their limitations. Using one case study as an illustrative example, some implications for the design of real-life systems are proposed.

BAUMER, J.M., [1980], Optimizing the appropriateness of technologies, in: de Schutter, J. & Berner, G. (eds.), Fundamental aspects of appropriate technology, Delft University Press, 178 - 187.

A cautionary note, echoing from the years of the fashion of "appropriate technology". The author suggests that technology needs to be adapted to a number of criteria to really serve development. He lists some reasons why the use of appropriate technology is not more widespread, and proposes a socio-economic method for filtering technical options.

BEHRENS, R., [1988], Discussion and proposals for a system of health monitoring in community based interventions, Department of Human Nutrition, London School of Hygiene and Tropical Medicine, Unpublished document.

An in-house document for a non-governmental organisation, suggesting different types of information that should be collected to monitor changes within rural communities, so that appropriate policies could be formulated in response. The following schemes were considered relevant: monitoring scheme for under-fives, nutrition and health education to the community, support and development of sanitation and water supply, use of child care centres for improving nutrition and child development. It proposes the use of a hand-held computer for data collection.

BERTRAND, W.E., [1985], Microcomputer applications in health population surveys: Experience and potential in developing countries, World Health Statistics Quarterly, 38, 91 - 99.

Considers how microcomputer applications could help in various stages of survey research. In the preliminary stage of study design and planning, computerisation can improve the speed of conducting administrative tasks and conducting literature surveys. Computers can also be useful in the sample selection stage for choosing a randomisation technique, as well as for processing, analysing and presenting the data collected. The author makes some practical recommendations for selecting and using hardware.

BERTRAND, W.E., ARMINANA, R. & AUVERT, B., [1988], Microcomputer applications in the health and social service sectors of developing countries, in: Bhalla, A.S. & James (eds.), D., New technologies and development: Experiences in technology blending, Lynne Reinner Publishers, Boulder, Colorado.

Examines the ways microcomputers could be used in health to improve health delivery services for the less privileged in developing countries, in particular, their use in planning, data collection and delivery services. Four case study summaries are included, illustrating the use of micros in rapid collection and analysis of both routine and survey health data, and in computer-aided diagnosis. A second section proposes a schema for evaluating the impact of computerisation, to cover short- term and long-term tangible as well as less tangible effects.

BESSANT, J., [1987], Information technology and the North-South divide, in: Finnegan, R., Salaman, G. & Thompson, K. (eds.), Information technology: Social issues, Hodder and Stoughton, 163 - 180.

Considers two possible responses of developing countries to information technology: production and adoption. It discusses the place of developing countries in the world economy, and assesses the possibility of others joining the small club of NICs (newly industrialising countries) in microelectronic production. The paper also suggests some factors that affect the rate of diffusion of IT applications. The author lists some possible options for the South, and discusses the role multinational corporations play in influencing the global economy.

BOARD OF SCIENCE AND TECHNOLOGY FOR INTERNATIONAL DEVELOPMENT (BOSTID), [1986], Microcomputers and their applications for developing countries, Westview Press.

Covering primarily the early years of the spread of microcomputers to developing countries, this book summarises some of the inroads microcomputer applications have made into solving information processing needs in developing countries. Chapter 4 concentrates on applications in health, including in broad categories database management, statistical analysis, modelling and simulation (including expert systems), and ancillary functions. The chapter also contains case studies of information systems in place in various areas of the developing world.

BOARD OF SCIENCE AND TECHNOLOGY IN INTERNATIONAL DEVELOPMENT (BOSTID), [1988], Cutting edge technologies and microcomputer applications for developing countries, Westview Press, Boulder, Colorado.

A second more recent volume that contains a series of articles on applications using state of the art telecommunications, expert system techniques and so on. The standard of papers included is very variable.

BOYOM SOP, F., [1990], Systemes experts appliques aux diagnostics des grandes endemies tropicales: le cas du paludisme, Faculte des Sciences/Labo. Informatique, Yaounde, Cameroun, Unpublished document.

The first sections discuss the need for assistance in the diagnosis of endemic tropical diseases, and the role expert systems can play. It describes rather sketchily the structure and operation of the prototype system on malaria.

BRIGGS, B.R., JAVETT, S.L., PISTORIUS, G.J., VAN DEN BERG, A.D.P. & DE KLERK, J.N. [c.1986], SASEP - A computerised diagnostic program, Randburg, South Africa, Unpublished paper.

This paper describes rather sketchily, the development of SASEP - a Sign and Symptom Evaluation Program, meant for use by registered nurses at the primary care level. It introduces basic concepts of expert systems, and lists some possible advantages of the use of SASEP in a developing country environment. It discusses some limitations of the system, but concludes optimistically about its potential in solving the manpower distribution problem.

BUCHANAN, B.G. & DUDA, R.O., [1983], Principles of rule-based expert systems, in: Advances in computers, 22, 163 - 211.

The authors summarise the key components of an expert system and the techniques used to represent knowledge, infer from it, and reason with uncertainty. They discuss the key concepts underlying the rule-based method.

BYASS, P., [1987], Computers in Africa: Appropriate technology?, Computer Bulletin, June 1987, 17.

A short article discussing the potential of computer technology in Africa, and possibilities for its use as an appropriate technology. Using the local area network installed in a research institution in The Gambia as an illustrative example, the author concludes that, used appropriately, computers will become as indispensable as they are in industrialised countries.

BYASS, P., [1988], A probabilistic approach to health care delivery in Tropical Africa, in: Reinhoff, O., Piccolo, U. & Schneider, B. (eds.), Expert systems and decision support in medicine, Lecture Notes in Medical Informatics, 36, Springer Verlag, 136 - 141.
Discusses the special needs for an appropriate computerised decision-support tool for health care in rural developing country settings. It describes the methodological approach used in the implementation of one such tool, and defines the terms and algorithm used for Bayesian inferencing in the system.

BYASS, P., HANLON, P.W., HANLON, L.C.S., MARSH, V.M. & GREENWOOD, B.M., [1988], Microcomputer management of a vaccine trial, Computers in Biology and Medicine, 18:3, 179 - 193.

Describes the improvements observed in using a microcomputer-based approach to manage a vaccine trial. The paper describes background details of the study, and the methods used in computerising a vaccination record and clinic call system. The results showing improved compliance are presented.

BYASS, P. & CORRAH, P.T., [1989], Assessment of a probabilistic decision support methodology for tropical health care, in: Manning, P., Zhineng, O. & Barber, B. (eds.), Medinfo 89, Elsevier (North- Holland).

Randomly selected patient records collected routinely at an outpatients department over a year were used to construct a database. This, combined with a methodology developed earlier, see Byass, 1988, make up a decision-support tool which has been tested, and is discussed in this article. The use of test cases, to assess internal consistency as well as diagnostic ability, is described and the results summarised.

BYTE, [1989], Small wonders - A review of portable computers, Byte, August 1989, 14:8.

A review of a range of recently released portable computers, summarising the main features of each.

CASLEY, D.J. & LURY, D.A., [1987], Data collection in developing countries, 2e, Clarendon Press.

Discusses the need for improved planning of surveys and various aspects of the process: deciding what data to collect, administration of censuses, use of sample surveys and case studies, the design of questionnaires, personnel management, fieldwork, data preparation, processing and analysis. Several examples of surveys are given.

CENTRE MONDIAL, [c.1984], Le micro-ordinateur aide au diagnostic et a la therapeutique, Report by the Centre Mondiale, Paris, 43 - 47.

Section in a Centre Mondial report, summarising the work of the project on computer-aided diagnosis for developing countries, see Goldberger and Schwenn, 1983; Goldberger et al., 1983. It describes MEDIT and MEDIC, the first a system for designing the knowledge base of an expert system, and the other a system for diagnostic and therapeutic advice. It gives a rough work plan, with details of pilot tests.

CHANDRASEKARAN, B., [1983], On evaluating AI systems for medical diagnosis, The AI Magazine, Summer 1983, 34 - 37.

This paper discusses the difficulties of evaluating medical diagnosis systems, and summarises experience to date in evaluating medical AI systems. He proposes a

procedure for evaluation, based on a modified Turing test, that could be used to measure both the accuracy of diagnosis and the structure of reasoning.

CHANIS, [1986], Child Health and Nutrition Information System, UNICEF Social Statistics Bulletin, 9:10.

An instruction booklet for the child monitoring system being implemented in Kenya. Illustrates the use of tally sheets, growth charts, patient registers, follow-up lists, and summary sheets.

CHAPMAN, N.G., [1987], Computers in health care at district level in Zimbabwe, Master of Public Health Dissertation, University of Leeds, England.

A dissertation that investigates the role computers could play at the district health care level in Zimbabwe. It briefly reviews the current health care system in Zimbabwe and issues of computers and development. It lists some of the hardware factors to be considered before implementation: cost, user friendliness, compatibility, reliability, duplication, repairability, special environmental problems, input/output devices (printers, plotters, backup devices, monitors, barcode readers), and communications. Some of the possible software applications that could be pursued are next listed: word processing, spreadsheets, accounting, statistics, drug control, asset control, personnel management, planning, patient registers, support of community health workers, library systems, computer-aided learning, computer-aided design, computer mapping, databases and operational research. A prioritised list is proposed, and a cost- benefit analysis for an ideal initial system is included.

CLANCEY, W.J. & SHORTLIFFE, E.H. (eds.), [1984a], Readings in medical artificial intelligence: The first decade, Addison Wesley.

Collection of articles (mostly previously published), reviewing the first years of AI applications in medicine. The four early AIM systems; MYCIN, INTERNIST, CASNET, and PIP are discussed comprehensively. Contains an extensive bibliography.

CLANCEY, W.J. & SHORTLIFFE, E.H., [1984b], Introduction:: Medical artificial intelligence programs, in: Clancey, W.J. & Shortliffe, E.H. (eds.), Readings in medical artificial intelligence: The first decade, Addison Wesley, 1 - 17.

Introduces the basic concepts differentiating AIM research from more conventional approaches used in the 60s. The concept of a knowledge base is defined, and ways of designing and representing captured knowledge summarised.

COLLINSON, P.O., JONES, R.G., HOWES, M., NICHOLLS, J., SHEEHY, N., BORAN, G.R. & CRAMP, D.G., [1988], Of mice and men - Data capture in the clinical environment, West Middlesex Hospital, UK, Unpublished document.

Results of a project investigating the use of alternative input devices for rapid and accurate data capture in critical medical care environments. It summarises all the different input technology options available. Comparative studies were conducted to compare the QWERTY keyboard, cursor control keys, mice, and graphic tablet options. In conclusion, the graphic tablet seemed the most appropriate tool.

COMMONWEALTH SCIENCE COUNCIL, [1986], Status of and computer applications (Africa) - Status country papers presented or contributed in regional workshop on fundamentals of microprocessor-based systems, Nairobi, Commonwealth Secretariat, CSC Technical Publications Series No 208.

The introductory paper overviews the status of computer applications in some commonwealth countries, giving a brief history of the first government installations. It also considers education and training facilities at the tertiary, secondary and primary levels. Applications to industry and commerce are mentioned. The paper assesses the need for computer policies and discusses some of the problems of computer diffusion. Nine country status papers are included.

CRISAN, C., KEITA, L. & CANTRELLE, P., [1988], Observation demographique suivie avec des micro-ordinateurs portables sur le terrain. Une experience en Guinee, in: Congres Africain de Population, Union Internationale pour l'Etude Scientifique de la Population, Dakar, November 1988.

A short article describing the experience of researchers in collecting data using portable computers in the field. A software program called SIC (Systeme Integre de Collecte) [Ferry et al., 1985] was used to design a computerised version of a demography questionnaire. The survey was conducted in both an urban and a rural environment. The authors discuss the problems of man-machine interaction, software bugs, and hardware durability.

CROFT, D.J., [1972], Is computerized diagnosis possible?, Computers and Biomedical Research, 5, 351 - 367.

Discusses the potential role of computer-assisted diagnosis, and summarises the many mathematical approaches that have been devised for implementing diagnostic models. Using ten commonly used methods, little difference in performance could be attributed to the differences in the models themselves, due to their close mathematical relationships. He suggests that future research should be directed not towards finding new methods, but in tackling some practical obstacles.

DANISH MEDICAL BULLETIN, [1984], Supplement 1, 31, 4 - 27.

A collection of articles on the relationship between developing countries and the pharmaceutical industry, which is characterised by a proliferation of brand names and unethical marketing practices. The articles span the work of the WHO Action programme on drugs, discussion of the misuse of drugs in the third world, and an assessment of the role of community health workers in providing drugs.

DEER, R. & LAURIA, D.T., [1985], The use of microcomputers in the health sector in developing countries, in: Munasinghe, M., Dow, M. & Fritz, J. (eds.), Microcomputers for development, CINTEC-NAS, 115 - 148.

This was written as part of a USAID 3 year project on the role of microcomputers in developing countries. It gives examples of ways in which they have been used, and can be used, to promote health. Applications of differing levels of sophistication are listed: database systems, statistical analysis, modelling and simulation, and ancillary equipment. An annotated bibliography based around these topic areas is included. Part of this paper has been reproduced in BOSTID [1986].

DELAPIERRE, M. & ZIMMERMAN, J.B., [1985], Utilisations et besoins, Terminal, December 1985, No 26, 10 - 14.

Information technology can be a tool for creating significant improvements in various sectors in developing countries. However, many geophysical and infrastructural constraints exist. The authors consider what policies can, or should, be implemented to overcome these problems.

DOUKIDIS, G. & FORSTER, D., [1990], The potential for computer-aided diagnosis of tropical diseases in developing countries: An expert system case study, European Journal of Operational Research, Special Issue on Developing Countries (in press).

An early article (published three years later) detailing some of the optimistic plans of the authors in initiating a project to implement a computer-assisted diagnostic system.

DREYFUS, H. & DREYFUS, S., [1986], Why expert systems do not exhibit expertise, IEEE Expert, Summer 1986, 86 - 90.

The authors challenge the optimistic dreams of artificial intelligence gurus, which the authors claim has attracted much interest from military and civilian managers. They argue that trying to capture sophisticated skills that include judgement is a misguided effort doomed to failure. They cite as reasons: humans know how as well as know that certain premises hold true; that many experts use intuition; that decision-making involves thinking with images and not just words; that the mind uses similarity measures. On all of these counts, expert systems do not match human expertise.

EAMSIRI, J., MALASIT, P., SONGSIVILAI, S. & CHONGSTITVATANA, P., [1987], Intelligent tutor for medical teaching, in: Proceedings of the regional symposium on computer science and its application, Bangkok.

This article presents 'Medical Tutor', a program for teaching medical students the differential diagnosis of anaemia. The tutoring strategy uses the expert module to assess the competence of the student, recorded in the student model. A limited evaluation was conducted.

EDITORIAL, [1989], Computer-assisted diagnosis, The Lancet, December 9, 1371.

This short opinion piece suggests that researchers who develop computer-assisted systems have made certain assumptions that do not necessarily hold: that treatment does not always follow logically from a diagnosis, that doctors have a capacity for self-correction although they may appear to be illogical in their decision-making, and that the importance of an accurate diagnosis may be questionable. He claims that research is still in its infancy and uses concepts that are too simplistic. He concludes that, although research must continue, computer- assisted diagnosis will not produce systems of worth in the near future.

EL KHOLY, A. & MANDIL, S.H., [1983], Microcomputers and health improvement in developing countries, WHO Chronicle, 37:5, 163 - 165.

This paper discusses the role that microcomputers can play in the collection and analysis of health data, to enable decision-makers to make reasoned judgements of the effectiveness of their policies. The authors propose that microcomputers be introduced at an intermediate level in the health care structure to eliminate the delays that occur if all information is centrally processed. The paper assesses some of the problems of the transfer of computer technology, but concludes that its implementation is compatible with the conditions in the developing world.

ELLIOTT, K. [1985], Introduction, in: **Appropriate Technology - Articles from the BMJ**, British Medical Association, 1 - 2.

A short and interesting synopsis of the problems of using simple yet effective technologies to improve widespread health problems in the developing world. The author also presents a list of criteria for considering a technology as appropriate.

ESSEX, B.J., [1975], Approach to rapid problem solving in clinical medicine, British Medical Journal, 5 July 1975, 34 - 36.

This paper describes how a set of problem-oriented flowcharts were developed, using information from outpatients in a Tanzanian hospital. In evaluating the charts with medical students, they proved to achieve high levels of repeatability, accuracy and rapidity. The author claims that their use may help to standardise referral patterns, and lead to an improved quality of medical care.

ESSEX, B.J., [1980], Diagnostic pathways in clinical medicine, 2e, Churchill Livingstone.
A set of diagnostic flowcharts developed for paramedical workers in tropical medicine. The introductory sections detail how the flowcharts were constructed and how they are meant to be used. Each chart is based around a major symptom, and a series of decision boxes and yes or no arrows lead to diagnoses. Additional notes are given for difficult signs and symptoms.

EVANS, J.R., HALL, K.L. & WARFORD, J., [1981], Shattuck lecture - Health care in the developing world: Problems of scarcity and choice, The New England Journal of Medicine, 305:19, 1117 - 1127.

The authors draw similarities between the current state of health provision in developing countries with the conditions existing in urban nineteenth century USA. They explain this likeness with a three stage evolutionary model of health service provision, dominated in turn by infectious diseases, chronic diseases, then personal health care. Several obstacles to achieving the WHO goals of health for all are listed and the problem of financial support of health services is discussed at length. They conclude that developing countries face a bewildering array of choices and the challenge is to choose an optimum strategy for making the maximum impact.

FERRY, B. & CANTRELLE, P., [1988], L'utilisation de micro-ordinateurs de terrain pour la collecte en demographie, in: Congres Africain de Population, Union Internationale pour l'Etude Scientifique de la Population, Dakar, Senegal, Novembre 1988, Session 1.2, 14 - 30.

An update on the Systeme Integre de Collecte (SIC) project (see Ferry et al, 1985). In the introductory sections, the authors present some of the problems of conducting demographic research in developing countries, the most serious consequence being the often lengthy time lag between collection and presentation of data. They discuss the role microcomputers can play at decentralised locations for different stages of the demographic survey process. Previous work by other organisations in recording data directly onto portable computers at the point of collection is summarised. The SIC software program for questionnaire preparation, data collection and analysis is described.

FERRY, B., BERGES, J.C., COUILLET, F. & CANTRELLE, P., [1985], La saisie et le traitement d'informations statistiques en milieu severe a partir de micro-ordinateurs portatifs, Projet Systeme Integre de Collecte (S.I.C.), Document de travail No 11, ORSTOM.

A working document detailing the background to this project on computer-assisted data collection under difficult field conditions. It describes the objectives of the project, the hardware used, the software developed, and the preliminary evaluations that have been conducted. It discusses some lessons learnt from the field trials, and how the system could be further improved and ultimately used in all stages of the survey process.

FISCHBACHER, C.M., [1988], Review of PCEA Chogoria Hospital information management system, Pentecostal Church of East Africa Chogoria Hospital, Kenya, Unpublished document.

Summarises the background and history to the current hospital information systems, covering the community health programme, hospital wards, financial records, stores, pharmacy, and other miscellaneous uses. The document reports on problems of the organisation of the system, the choice of hardware, data storage facilities, software used, reporting formats, and staff training.

FLIKEID, J.R., MACKINTOSH, D.R. & COOK, G.B., [1986], Clinical microcomputer software for developing countries, in: Salamon, R., Blum, B. & Jorgensen, M. (eds.), Medinfo 86, Elsevier (North-Holland), 296 - 300.

Discusses a suite of programs developed to assist mid-level practitioners in developing countries. This includes an expert clinical assistance module (currently exists as a prototype covering a few disease categories), immunisation scheduling, contraception determination, high risk pregnancy determination, nutrition training, and medical record keeping. The paper describes plans to make the software available in other languages.

FORSTER, D. & DOUKIDIS, G., [1989], ESTROPID: An Expert System for TROPIcal Diseases, in: Hunter, J., Cookson, J. & Wyatt, J. (eds.), AIME 89, Proceedings of the Second European Conference on Artificial Intelligence in Medicine, Lecture Notes in Medical Informatics 38, Springer-Verlag, 88 - 92.

This paper presents a scenario for implementing medical expert systems in developing countries. It discusses why such systems have been suggested, the principal factors that determine successful use, and how they can be adopted for routine use. It introduces ESTROPID, not as a revolutionary new system, but as a simple tool for diagnosis to be used to investigate why many systems fail. The goal in this development is not primarily to produce an optimally efficient model in technical terms, but threefold: to establish whether such systems are of any ultimate use beyond academic research, to identify what factors determine its successful implementation, and define how they can be evaluated within a generalised framework.

FORSTER, D., [1990], Health informatics in developing countries: An analysis and two case studies, Ph.D. thesis, London School of Economics and Political Science, University of London.

This thesis relates informatics to the problems of health and medicine experienced in less developed countries. It evaluates the potential of health informatics and investigates the issues that constrain successful implementations. This serves as a basis for establishing a generic description of viable computer applications in the developing world. The thesis contains two case studies from sub-Saharan Africa. The first, undertaken in The Gambia, is based on a computer-assisted data collection system used in a longitudinal child health survey. The second, undertaken in Kenya, relates to a medical decision-aid system used in an outpatient clinic of a district

hospital. A generalised evaluation approach is proposed, which includes components related to functional and human perspectives as well as the anticipated benefits to the health care system. This framework is used to summarise the case study findings. The thesis concludes by suggesting some guidelines for the design and evaluation of future health information systems.

FORSTER D., BEHRENS, R., CAMPBELL, H. & BYASS, P., [1990], The evaluation of a computerised field data collection system for health surveys, Bulletin of the WHO [to be published].

The Field Data Collection System (FDCS) has been developed on a hand-held computer, to allow questionnaire specification using prompts and range definitions which are then used to check data during input in the field. In a field trial, the computer system was used in an ongoing malaria morbidity survey to evaluate data quality, preparation time and user acceptability. The results show improved data quality, reduced interview times, using a method acceptable to both interviewers and respondents. FDCS may have a useful role in improving the quality of data on health care in developing countries.

FOUNTAIN, D.E., [1982], Infirmier, Comment traiter votre malade, Simavi, Haarlem, Holland.
A set of flowcharts produced in a heuristic fashion. Each chart covers a major symptom and is supplemented with detailed notes.

FOX, J., [1984], Expert systems: Towards a routine technology, in: Roger, R.H., Willems, J.L., O'Moore, R. & Barber, B. (eds.), Medical informatics Europe 84, Lecture Notes in Medical Informatics, 24, Springer-Verlag, 19 - 23.

Describes expert systems developed so far as merely decision support systems that have had little influence on routine clinical practice. The author asserts that, to be acceptable, systems must not only be competent, but also intelligible, accountable and maintainable. More research needs to be conducted on evaluation, knowledge base maintenance, explanation capabilities, the integration of new input/output devices, and methods of representing uncertainty. For progress, it is important that researchers learn what areas to leave well alone.

FOX, J. & FROST, D., [1985], Artificial intelligence in primary care, in: De Lott, I. & Stefanelli, M. (eds.), Artificial intelligence in medicine, North-Holland, 137 - 154.

The authors claim that, unlike expert systems for constrained and controlled situations, systems for primary care are more difficult because of the range of problems dealt with, the need to include patient management over time, and the personal nature of the consultation process. The paper introduces the work of a British general practitioner, and the need for improved care and support. The potential role and characteristics of a primary care expert system are described, and the design of the experimental package that has been developed is explained.

FOX, J., GLOWINSKI, A. & O'NEIL, M., [1987], The Oxford System of Medicine: A prototype information system for primary care, in: Fox, J., Fieschi, M. & Engelbrecht, R. (eds.), Proceedings of the First Conference on artificial intelligence in medicine, Lecture Notes in Medical Informatics, 33, Springer Verlag, 213 - 226.

Describes a project which aims to design a knowledge based general practice information system for clinical decision support. The OSM project is as yet experimental, and the prototype was developed to test technical feasibility, and investigate practical aspects of implementation. Much attention was paid to the design of the user interface. The knowledge base is structured in a layered and modular

manner for ease of development, maintenance, and publication of medical knowledge. The decision making procedure used is also described. Although many questions remain, the authors are optimistic about the opportunities for future development of the prototype.

GASCHNIG, J., KLAHR, P., POPLE, H., SHORTLIFFE, E. & TERRY, A., [1983], Evaluation of expert systems: Issues and case studies, in: Hayes-Roth, F., Waterman, D.A. & Lenat, D.B. (eds.), Building expert systems, Addison-Wesley, 241 - 280.

The role of evaluation as a continuing exercise is emphasised. Different levels of evaluation, and difficulties of carrying it out are discussed. Some design issues for the evaluation of expert systems are suggested (including the consideration of what aspects to evaluate, when and how the trial should be designed). Two case studies are included.

GASS, S.I., BHASKER, S. & CHAPMAN, R.E., [1986], Expert systems and emergency management: An annotated bibliography, US Department of Commerce, NBS Special Publication 728.

An indepth review of literature on expert systems, to examine ways in which they could be applied in emergency management operations. Each chapter consists of a brief topic essay and a set of references which expand on the theme. Topics include: the nature of emergency management, reasoning and methodological issues in the design and development of expert systems, user interface considerations, and applications of expert systems.

GOLDBERGER, H. & SCHWENN, P., [1983], Man-machine symbiosis in the assistance and training of rural health workers: A proposal, in: Pages, J.C., Levy, A.H., Gremy, F. & Anderson, J. (eds.), Meeting the challenge: Informatics and medical education, Elsevier (North-Holland), 295 - 306.

Describes the problems of providing primary health care, and the central role of rural health workers. Their adequate training and support is of vital importance. The paper discusses ways of augmenting their skill: providing computer-assisted diagnostic and therapeutic support (using an enhanced flowchart-based approach), computerising clinical records (possibly using smart cards for patient data), and for training (using multimedia). A proposal is made for the type of system that needs to be developed to meet all these needs, and be sustainable in the harsh rural environment it is meant to be used in.

GOLDBERGER, H., SCHWENN, P., EMANUELLI, X., CHESNAIS, A., DHERBECOURT, N. & DE FERAUDY, H., [1983], Computer aided medical care in developing countries, Report to the Scientific Council, October 1983, Unpublished document.

A working document, summarising the work of the Centre Mondial group up to 1983, and their plans to 1985 for implementing the suite of computer programs developed. They discuss the problem definition, list their research questions and include a project description.

GOWERS, P., [1987], Selection of CHWs, A case study from The Gambia, Footsteps to Health, March 1987, No 5, 4 - 5.

This short article describes the implementation and operation of The Gambia's primary health care programme, which started in 1981. Based on the principle that community health workers (CHWs) are best chosen by the community, a procedure has been established for their selection. Potential villages are selected according to geographical

position, existing health facilities and population size. A meeting is held with the villagers and the scheme explained. They are asked to form a committee and to select a worker, not necessarily literate, who is willing to be trained, and to work part-time. The strength of the village's commitment, particularly for the support of the CHW, is reviewed before the worker chosen is trained.

GREENFIELD, T., [1980], Computers and Health, Queens University of Belfast, New Lect. Series 125.

An inaugural lecture delivered by a professor of medical statistics at the University of Belfast. He considers a range of computer applications for health and includes: patient management in general practice and possibly diagnostic support, laboratory analysis in hospitals, and computer interviewing of patients.

GUPTA, G.K., [1987], Role of computer technology in developing countries, Information Technology for Development, 2:1, 43 - 58.

This paper discusses the importance of computer technology in developing countries, despite their generally unpromising characteristics. The author explores the range and diversity of developing countries, classifies them into six groups: newly industrialising countries (NICs), middle income countries, countries with very large populations, those with medium-sized, small and very small populations. He suggests that each group faces different difficulties for computer production and utilisation, and can make different kinds of responses for effective use of computer technology.

HARRISON, P., [1990], Too much life on earth?, New Scientist, 19 May 1990, 28 - 29.

A short article on the relationship between the population explosion and environmental problems. The role of family planning in controlling population explosion and consequently, resource use, is often put forward as a solution for many developing country ills. Others disagree. The author argues that population is only one of the factors that lead to environmental degradation: levels of consumption and the technology needed to satisfy that consumption are two other factors. He backs up his argument with some data and assesses the share of the blame that can be attributed solely to population growth.

HEGGENHOUGEN, K., VAUGHAN, P., MUHONDWA, E.P.Y. & RUTABANZIBWA-NGAIZA, J., [1987], Community health workers - The Tanzanian experience, Oxford Medical Publications.

A thorough review of the role played by community health workers in Tanzania, with background details of the history of the Tanzanian health systems, the Arusha initiative, and the structure of the health system. The views of villagers about their local community health workers, the current practice of community health workers and their understanding of their role are explored. This information is supplemented by 5 village examples, as observed by the authors. The book concludes with a list of critical issues for their continued support and effectiveness.

HELLING-BORDA, M., [1983], The essential drugs concept and its implementation, DAP 85.1, World Health Organisation.

The rationale and history behind the Essential Drugs Action Programme is described. The process of drawing up the essential drugs lists by expert committees is outlined. The problems of implementing the concept at a global level and the need for a national drug policy is discussed. Some examples of country programmes are given.

HILL, A.G., [1987], Use of demographic data and health statistics to inform primary health care, Centre for Population Studies, London School of Hygiene and Tropical Medicine, UK.

Since the Alma Ata declaration, many developing countries have adopted the concept of primary health care. There remain problems in developing appropriate data collection and analysis methods for monitoring and evaluating primary health care programmes. This article examines the need for sensible selection of health indicators and options for their collection, either routinely or survey-based. The health data systems in Mali, Senegal, The Gambia and Sierra Leone are described as illustrative examples.

HOLLNAGEL, E., [1989], Evaluation of expert systems, in: Guida, G. & Tasso, C. (eds.), Topics in expert system design, Elsevier Science Publishers, 377 - 416.

Expert system evaluation is still in its infancy and there is no generally recognised methodology. This paper analyses some methodological issues about the quality of the expert system in use. It considers some of the problems in the application of expert systems, in particular, definition of their roles. Some evaluation criteria are discussed, and a choice of options in methodological design outlined.

HORN, W., [1983], ESDAT - Decision support for primary care, in: Van Bemmel, Bell & Wigertz (eds.), Medinfo 83, North-Holland, 484 - 487.

Describes an expert system for diagnosis and therapy, for use at the primary care level by inexperienced physicians. The knowledge base is composed of static and dynamic knowledge. Static knowledge is represented in a semantic net, hierarchically ordered and stored in a database. Dynamic knowledge is built by activating nodes of the net using a blackboard methodology for storing currently activated hypotheses. At present, the knowledge base covers rheumatology. The reasoning process generates and tests hypotheses, using a focusing mechanism for improving performance. The system has been tested experimentally and needs further improvements in speed, refinement of knowledge base and user interface.

HORNUNG, B.R., [1987], Expert knowledge based simulation for health planning in the third world, in: Proceedings of Medical Informatics Europe 87, Rome, 1349 - 1354.

Simulation is a particular experimental technique that allows the testing of alternative planning strategies. Health planning thus becomes a rational activity rather than based on intuition. The paper describes one simulation technique based on deductive reasoning. It includes an example of a model on the effect of the development of the health care system on Mexican society.

HURTADO, M.E. & NEWMAN, A., [1986], March of the barefoot microchip, South, September 1986, 111 - 114.

A journalistic article, investigating the potential of microcomputer-based diagnostic support in developing countries. The authors interview a number of researchers, some of whom have written articles included in this bibliography. The article contains numerous application examples.

JAIN, A.K., [1987], Expert systems: Prospects for developing countries, United Nations Industrial Development Organisation.

Despite its title, only five pages of this review document are devoted specifically to the application of expert systems in developing countries. The report includes an overview of the components of an expert system, some possible application areas, some case studies, stages in the development of an expert system, some commercially available tools and systems, and potential for developing countries. The appendices list some expert systems by function, and the details of a project proposal for an expert system for transfer of technology agreements.

JONES, R., MCLACHLAN, K. & BELL, G., [1990], Healthpoint: A public-access health information system, Current perspectives in health computing, 65 - 69.

An investigation into the use of a public access information system when tested at a general practice in Scotland. A menu driven system using a maximum of eleven keys, nine of which are colour coded keys corresponding to coloured menu choices. The database contained information on disease prevention, drugs, contraception, women's health, AIDS and a few other topics. Evaluation included testing with staff, students, and visitors at the first stages, then a further public evaluation was performed. The paper summarises the results obtained and reasons why some patients did not use the system. The authors conclude that the study shows potential for further system development.

KASTNER, J.K., DAWSON, C.R., WEISS, S.M., KERN, K.B. & KULIKOWSKI, C.A., [1984], An expert consultation system for frontline health workers in Primary Eye Care, Journal of Medical Systems, 8:5, 389 - 397.

The lack of suitable primary eye care blinds many people in developing countries. Using the WHO guidelines for health workers, the PECM was developed using the EXPERT expert system shell as an environment for specifying the knowledge base. Automatic translation of the resulting expert system is made into BASIC to run on microcomputers. Anticipated field testing is discussed, described more fully in Ostroff et al., 1985; 1986.

KELSEY, R., [1988], Expert systems as a preliminary design tool for drinking water supplies in developing countries, Science Technology and Development, 6:1, 13 - 20.

Three major distinguishing features of expert systems are identified. Expert systems can potentially be applied in developing countries as consultants, decision-support tools, checklist systems, means of technology transfer and training, intelligent front ends, and inter- disciplinary linkage. These possibilities are examined with particular reference to drinking water supplies. The author defines more carefully the case for an expert system in this application domain, and its expected function. He discusses some of the advantages and disadvantages of expert system use, and also describes a prototype to help plan the design of drinking water supply systems.

KHALIL, T.M. & WALY, S.M., [1988], Planning for health care technology transfer, Technology management publication, No 1, 424 - 431.

There is increasing use of technology in the provision of health care including its use in diagnosis and treatment, life- sustaining devices, and aids to the handicapped. Computers are now an integral part of hospital life in developed countries. Developing countries need to plan how technology should be should be used for maximum effectiveness. The necessary infrastructure and manpower required to absorb the new technology must be developed. The authors list a number of technical services and manpower requirements.

KING, K., [1990], Artificial intelligence applications for medicine in developing countries, Final report, Department of Artificial Intelligence, University of Edinburgh, UK.

A collection of documents about a one year feasibility study on the potential of applying AI techniques to support community health workers in medical decision-making in developing countries. It includes a summary of the main conclusions of the year's investigation, a proposal for a more practically oriented investigation into how health workers make decisions and how they need to be supported, the current doctoral programme of the researcher, and details of a hypercard implementation of a manual on sexually transmitted diseases.

KING, K. & BECK, H., [1990], Medical AI systems as appropriate technology for developing countries, Knowledge Engineering Review (in press).

An interesting review of current literature on the potential of AI for developing countries. It summarises seven expert systems that have been designed for developing countries. It lists several issues that would make AI an appropriate technology, and discusses what would be needed to design an appropriate and practical system.

KING, M., [1990], Health is a sustainable state, The Lancet, September 15, 1990, 336, 664 - 667.

This controversial article discusses the potential damage that uncontrolled population growth can wreak on ecological sustainability. It discusses the demographic trap and the inevitable ecological collapse that will ensue in areas where falling death rates are not associated with falling birth rates. The ultimate ethical dilemma is in deciding whether deliberate measures of mortality control should be set, for example, not implementing an oral rehydration scheme. The author calls for immediate changes in political and social attitudes to address the implications of continued desustaining practices.

KLUZER, S., [1990], Computer diffusion in Black Africa: A preliminary assessment, in: Bhatnagar, S.C. & Bjorn-Andersen, N. (eds.), Information technology in developing countries, North-Holland, 175 - 188.

Attempts the difficult task of showing the extent of computer penetration in sub-Saharan Africa. It discusses the rate of diffusion, and presents some data on trade in computer technology. It assesses some of the factors the contribute to computer diffusion: multinationals, computer companies, international organisations, governments and private companies. It investigates the role of computer policies, human resources and training facilities.

KOHLI, F.C., [1986], Information policy issues in developing countries, in: Kugler, H.J. (ed.), Information processing 86, North- Holland, 591 - 597.

This paper summarises some reasons for the initially slow growth of computer technology in developing countries. It outlines why developing countries should aim towards rapid adoption: complexity of societal problems, to improve productivity, for improved precision by automation, education, management and monitoring of planning, disaster and crisis management, and rural development. It discusses policy issues and options for developing countries: computer hardware, software production, development of human resources, societal concerns, national planning, employment and education.

KORPELA, M., [1988], Ergonomics of developing countries, Occasional papers 3, University of Helsinki, Institute of Development Studies.

This paper first introduces the terms 'developing countries' and 'ergonomics'. It summarises some of the research work to date, outlining some of the issues that have been studied: physical environment, physiology, psychology, cultural features, and ergonomic design. The author also touches on the need for ergonomic studies into the nature of successful technology transfer. He discusses why such studies are important for developing countries and summarises some of the work being done in Finland.

KORPELA, M., [1990a], Health care informatics in the context of a developing country: The Ife project - Report 1989, University of Kuopio Press, Kuopio, Finland.

An absorbingly personal account of the author's information system project in Nigeria. An intriguing mixture of personal insights, family diary, political tension and computing. It covers preparations for the case study and a description of the process of developing a hospital information system. The author also assesses successes, gains and prospects in a more formal fashion in his concluding remarks.

KORPELA, M., [1990b], The role of information systems ergonomics in developing countries, in: Bhatnagar, S.C. & Bjorn-Andersen, N. (eds.), Information technology in developing countries, North- Holland, 265 - 275.

Disappointments in technology transfer projects to developing countries have indicated that technology cannot be applied independently of its social context. Macroergonomics of information systems in developing countries is a new but important multi-disciplinary approach, dealing with man, technology, environment and work. The paper summarises the five main features of this approach: analysing actual work activity, investigating the existing experience of workers, analysing personal life settings, including participation in systems design, and allowing for total transfer of technology.

KRYSTALL, A., [1986], Introduction of microcomputers for management needs - Sharing the experience of Chogoria Hospital, Thunder and Associates Inc, Nairobi, Kenya.

Report of a workshop meant to disseminate the methods used in implementing the PCEA Chogoria Hospital Information System [see Fischbacher, 1988]. It covers various aspects of the implementation process, and more detailed information on some of the specific hospital applications. The positive benefits of the system are listed, and the lessons learned outlined.

KULAKOW, A.M., [1983], Applications of informatics to health care services and training in developing countries, in: Pages, J.C., Levy, A.H., Gremy, F. & Anderson, J. (eds.), Meeting the challenge: Informatics and medical education, Elsevier Science Publishers, 307 - 312.

The author claims that an important problem in the provision of health services is in the training of health staff and their ongoing support. Computer technology is attractive but its implementation in rural settings is constrained by several factors. These are attributed to predominantly urban patterns of expertise; limited training infrastructure and access to technical information; planners with little access to health information; lack of communications; and haphazard health management. Opportunities exist for computer applications particularly in management, training and diagnostic support.

KULIKOWSKI, C.A., [1987], Artificial intelligence in medicine: A personal retrospective on its emergence and early evolution, in: ACM conference on the history of medical informatics, 199 - 206.

This paper traces some of the major developments in AIM during the 1970s. It introduces its origins in statistical decision- making techniques using conventional multivariate methods, and the gradual development of interest in symbolic manipulation techniques. It describes the author's involvement in research efforts and his role in the development of CASNET. By the end of the 1970s, research work was consolidated and a second generation of systems had started.

LAND, F., CORNFORD, T. & DOUKIDIS, G.I., [1988], In search of the expert system product, in: Proceedings of the Joint International Symposium on Information Systems, Sydney, Australia, February 1988.

Expert systems have been academically successful since the 1970s but a major market for such products is just emerging. This paper discusses some tools of expert system design (shells, programming languages, and environments), and defines 12 requirements for the broadening of the scope of these tools. Four classes of current expert system products are described. It concludes with an assessment of how the market might evolve.

LINDBERG, D.A.B., [1979], Information systems for rural health: Problems and potential benefits, in: Health Care Technology Evaluation, Proceedings, Springer-Verlag, 61 - 65.

Analyses the potential of medical information systems in the rural context and outlines some of the possible uses. It discusses barriers to diffusion of the technology, due to technical, social, organisational and managerial problems. Some of these may be exacerbated in the rural setting, but new developments in microcomputer and telecommunications technology offer some interesting possibilities.

LINDBERG, D.A.B., [1987], In praise of computing, in: ACM Conference on the history of medical informatics, 1 - 4.

An interesting historical view of the spread of medical informatics and an account of the author's gradual involvement in its application. It traces the history of automation from the days of valve-controlled processors and paper tape readers to the dawn of the electronic age.

LONGE, O., [1981], Computer applications to basic needs of developing nations, in: Bennett, J.M. & Kalman, R.E. (eds.), Computers in developing nations, North-Holland, 189 - 193.

Some basic development needs are education, health, employment, food and housing. The paper discusses how computers can be valuable tools in helping to provide for these needs, and listing some of the possible applications. A lot, however, depends on governments and their approach to effective computer utilisation.

MACHADO, R.J., DA ROCHA, A.F., RAMOS, M.P. & GUILHERME, I.R., [1990], Heuristic learning expert system, IBM Rio Scientific Centre, Brazil, Unpublished document.

A paper detailing the development of an expert system architecture. Neural networks and genetic algorithms are used in the HELAES system, whose main functions are inference, inquiry, explanation, knowledge acquisition, learning by example, and database management of cases. How all these functions are achieved is explained. The architecture has been applied to an expert system for the diagnosis of renal diseases.

MEINDL, J.D., [1985], Micros in medicine, in: Forester, T. (ed.), The information technology revolution, Basil Blackwell, 359 - 371.

The author gives examples of the widespread application of microcomputers in medicine. He includes uses in medical research (modelling biological and pharmacological processes), medical data collection (storage and retrieval of standardised medical records), medical decision-making (to solve clinical diagnostic problems under uncertainty), computed tomography (image production), ultrasonic imaging (for images of soft tissues), clinical laboratories (interfacing equipment with computers), interpretation of data from diagnostic tests (abnormal results are flagged), monitoring of critically ill patients (for continuous reliable information on patients in intensive care), aids for the handicapped (to increase their functional abilities).

MILLER, P.L, [1988], Evaluation of artificial intelligence systems in medicine, in: Miller, P.L. (ed.), Selected topics in medical artificial intelligence, Springer Verlag, 202 - 211.

The author separates evaluation into 3 possible levels: subjective assessment, validation of knowledge, evaluation of diagnostic ability. The article examines the issues underlying these forms of evaluation and discusses how several study evaluations fit into this classification.

MOON, Y.S. & LO, T.F., [1988], ROPES - A rule-based outpatient expert system, in: Reinhoff, O., Piccolo, U. & Schneider, B. (eds.), Expert systems and decision support in medicine, Lecture Notes in Medical Informatics, 36, Springer-Verlag, 38 - 43.

The paper describes ROPES, an outpatient diagnosis program designed to assist medical doctors in making rapid consultations. The system uses a categorical approach to classify the patient's diseases using Essex's principles [Essex, 1980]. Using this set of possible diseases, a backward reasoning process is implemented to confirm or reject these diseases. An explanation facility is included.

MURRAY, G.D., [1985], Computer-aided diagnosis and teaching, in: MacFarlane, P.W., Computer techniques in clinical medicine, Butterworths, 214 - 221.

The introduction discusses some possible types of applications of computer-aided diagnosis. One important prerequisite for diagnostic systems is a data bank, but there are some difficulties in their construction: choosing indicants, costs of indicants, availability of information, scales of measurement and the method of data collection. It outlines two techniques, based on statistical modelling and the use of diagnostic keys. It concludes by suggesting that computer-assisted learning is one obvious extension of diagnostic systems.

NDONGKO, W.A. & ANYANG, S.O., [1981], The concept of appropriate technology: An appraisal from the Third World, Monthly Review, February 1981, 35 - 43.

The authors challenge the common assumption that developing countries must follow in the technological footsteps of industrialised countries. Technology transfer practice has been assuming too much about the ease of transfer, its desirability or suitability. Many projects have proved ineffective in practice, indicating the need for "appropriate technology". The authors' view is that this does not necessarily hold, and that in developing countries, it is more important to adapt technology to suit their needs in an "intermediate" fashion.

NILSEN, S.E., [1979], The use of computer technology in some developing countries, International Social Science Journal, 31:1, 513 - 528.

Discusses the role of multinationals in the marketing of computers to developing countries, and cites the example of IBM in India. It lists some of the applications that are being pursued, mainly administrative in nature, but often underutilised. Countries are classified according to Computer Industry Development Potential Index to assess their short-term potential for developing data processing technology. Options for computer use are considered, as well as the need for training professionals and considering the potential impact on employment patterns.

OBENSON, P., [1983], Computer science research in Africa: Needs, priorities and problem - The IAI setting, presented at UNESCO Regional Workshop on Research and Application of Informatics in Africa, Lagos, Nigeria, December 1983.

Presents a perspective on informatics research at the Institut Africain de l'Informatique (IAI). It outlines the current state of computerisation in African countries. Some of the problems of conducting research are discussed. The author describes the Institute's mandate, and the SPECS programme which aims to develop methodologies and tools for all phases of information system design and create a design support environment.

OKOT-UMA, R.W'O., [1988], Information technology applications in developing countries: A synthesis perspective, presented at British Computer Society seminar on information technology applications in developing countries, London, March 1988.

The author explains the computer capability transition levels matrix, which outlines the characteristics of various levels of IT capability, and the steps needed for transition from one level to another. The four levels are initial, basic, advanced and operational. All the Commonwealth developing countries are classified according to this matrix. Various sectoral needs are discussed for each level of the transition stage.

OSTROFF, J.H., DAWSON, C.R., KASTNER, J.K., WEISS, S.M., KULIKOWSKI, C.A. & KERN, K.B., [1985], An expert advisory system for primary eye care for developing countries, in: Karna, K.N. (ed.), Expert systems in government symposium, Washington, Computer Society Press, 490 - 495.

See Ostroff et al., 1986.

OSTROFF, J.H., DAWSON, C.R., KASTNER, J.K., WEISS, S.M., KULIKOWSKI, C.A. & KERN, K.B., [1986], Preliminary results from field testing of an expert advisory system for primary eye care in developing countries, in: AI and Advanced Computer Technology, Proceedings of the 2nd Conference, Wheaton, Illinois, 12 - 17.

Summarises information presented in an earlier paper, Kastner et al , 1984, and presents additional information on the testing of the model using hypothetical cases, real cases collected in a US health centre, and cases from Yemen. The system is expected to be tested in Tunisia and Egypt.

PANKHURST, R.J., [1980], Medical diagnosis in developing countries, Computers in Biology and Medicine, 10, 69 - 82.

The need for medical diagnostic services in health systems of developing countries is described, and one manual solution to the problem outlined - diagnostic flowcharts [Essex, 1980]. To construct the flowcharts, the developers started from a list of diseases and the tabulation of their associated symptoms and signs. Using this database, automated checking procedures were used to verify the stored information, and then to construct diagnostic keys. This method is similar to polyclave techniques used by biologists.

PARTRIDGE, D., [1989], To add AI, or not to add AI?, in: Kelly, B. & Rector, A. (eds.), Research and Development in Expert Systems V, Proceedings of Expert Systems 88, BCS Workshop Series, Cambridge University Press.

The author discusses the potential for adding AI to practical software development, arguing that AI promises a qualitative leap forward in the power of computer software. He describes four facets of software power: responsiveness to user, applications in totally new domains, responsiveness to a changing environment, and an ability to monitor itself. The paper examines some of the difficulties with current software technology, and some of the differences between conventional software engineering problems and artificial intelligence problems. The author concludes that there are still many unanswered problems before AI techniques can be satisfactorily applied to conventional software problems.

PORENTA, G., PFAHRINGER, B., HOBERSTORFER, M. & TRAPPL, R., [1988], A decision support system for village health workers in developing countries, Applied Artificial Intelligence, 2, 47 - 63.

The sources of knowledge for the decision-support system described in this paper are presented. The development environment, the different representation techniques used for the diagnosis modules, and the structure of the therapy module are explained. A discussion of further work that needs to be done before field testing follows. A sample session is included in the appendix.

RATEAU, O., [1981], Informatics: Evolution and use in the 1980's, with particular reference to developing countries, in: Bennett, J.M. & Kalman, R.E. (eds.), Computers in developing nations, North-Holland, 3 - 9.

This paper discusses two major characteristics of the international community: the continuation of inequality between industrialised and developing nations; and the emergence of an information society in which computers will play an increasing role. Several trends in informatics will increase their possibility for application in the developing world: decreasing costs, increasing miniaturisation, better interfaces, and improved telecommunications. Some possible applications are listed, some of the risks discussed, and some conditions for success proposed.

RAUCH-HINDIN, W.B., [1986], Artificial intelligence in business, science, and industry. Volume 1 - Fundamentals, Prentice Hall.

RAUCH-HINDIN, W.B., [1985], Artificial intelligence in business, science, and industry. Volume 2 - Applications, Prentice Hall.

Although often haphazard in presentation, these two volumes provide a wide coverage of many AI applications in an informal and informative manner. The summaries of domain areas, techniques and tools available are good introductory summaries. The section on AI applications in chapter 9 of volume 2 describes three knowledge based systems currently in use: PUFF, CARE and HELP.

REITER, E., [c.1987], Some comments on computers in developing countries, Department of Artificial Intelligence, University of Edinburgh, UK, Unpublished document.

This paper discusses some the following issues: problems of using computers (environmental, lack of personnel, poor infrastructure, language difficulties, access to information), local hardware and software development, and other miscellaneous issues. The author concludes with some observations and recommendations for policy issues.

REITMAIER, P., [1985], Child health map: A computer-based method for the registration and mapping of the nutritional status, the participation in immunisation programs and the breast feeding rate in child populations of underdeveloped countries, University of Heidelberg, Germany.

Lists the objectives and requirements of the nutritional surveillance system, the hardware selected, and the general structure of the software developed. The paper concentrates on the graphical presentation techniques used to summarise the data collected.

REITMAIER, P., DUPRET, A. & CUTTING, W.A.M., [1987], Better health data with a portable microcomputer at the periphery: An anthropometric survey in Cape Verde, Bulletin of the World Health Organisation, 65:5, 651 - 657.

The authors discuss some of the problems in routinely collecting accurate health data. It describes a computer-based method for collecting anthropometric data, checking data input, and assessing nutritional status. The system has been tested in Cape Verde. See also Reitmaier [1985].

ROMER, M.D. & LAURSEN, H.F., [1989], The role of expert systems in technology transfer to developing countries, in: Sadananda, R. & Austriaco, N.C. (eds.), Proceedings of the International Conference on Expert Systems for Development, 155 - 162.

The paper starts by discussing some of the motivations for building expert systems: prevent loss of expertise, to improve productivity, to structure and codify expertise, to reduce decision-making time. It also outlines some possibilities and limitations. As an example, the manpower planning project in the Thai civil service is described. The lessons learnt from this implementation are listed.

ROSSI-MORI, A. & RICCI, F.L., [1988], On the assessment of medical expert systems, in: Reinhoff, O., Piccolo, U. & Schneider, B. (eds.), Expert systems and decision support in medicine, Lecture Notes in Medical Informatics, 36, Springer-Verlag, 292 - 297.

The authors explore the similarity between expert system evaluation and the testing of drugs. They suggest a methodology for evaluating systems that is extended beyond technical criteria. It covers four levels of evaluation, with growing width and subjectivity: raw efficiency of the system itself, effectiveness in the user's environment, long-term effects on user behaviour, and effectiveness on the health problem.

ANDERS, D., [1987], Reorganisation of the health sector - The way forward in the light of the Zimbabwean experience, in: Towards a national health service, Proceedings of the 1987 NAMDA Annual Conference, 88 - 98.

An interesting paper giving a historical perspective of the development of the Zimbabwean health service. Pre- independence, there were two widely differing disease profiles for the black and the white populations. Health care was provided by an amalgam of different organisations - mining industry, mission hospitals, and so on. After independence, a primary health care approach was adopted for a nation-wide, unified service. Certain strong policy measures were taken, but despite these, there remain problems caused by the burgeoning private health sector, and economic recession.

SCHWARE, R. & TREMBOUR, A., [1985], Rethinking microcomputer technology transfer to third world countries, Science and Public Policy, 12:1, 15 - 20.

The problems of introducing microcomputers into developing countries are discussed. The authors attribute some of the increasing demand for information technology to external pressures for computerisation, sometimes resulting in ill- conceived projects. An example of one such project is given. The authors stress the need for accurate manual data systems before computerisation, and list some recommendations for effective system implementations.

SEYMOUR, D.G., GREEN, M. & VAZ, F.G., [1990], Making better decisions: Construction of clinical scoring systms by the Spiegelhalter- Knill-Jones approach, British Medical Journal, 300: 223 - 226, 27 January 1990.

This article presents the results of a study investigating the practical use of a simple system of scoring information to help in risk assessment of individual patients. The technique is based on a mix of statistical techniques, used to calculate weights for variables included in a training set. From these, probability prediction scores can be easily obtained by arithmetic manipulations and reference to the constructed table. This method was successfully used to predict postoperative respiratory complications in a group of elderly surgical patients.

SHANKS, J.M., [1989], Information technology and survey research: Where do we go from here?, Journal of Official Statistics, 5:1, 3 - 21.

This paper reviews the rationale behind computer-assisted surveys, and the impact they have had on cost, quality and complexity of survey research. It discusses ways of integrating computer-based activities into the traditional survey research process, difficulties and alternative strategies for technical integration.

SHIRES, D.B., [1982], Health informatics in a changing world, AGORA, July/December 1982, 24 -25.

A brief appraisal of the dilemma of introducing health informatics into developing countries, basically addressing the question of whether this is a justifiable use of resources?

SHIRES, D.B., [1983], Health informatics for all by the year 2000, Methods of Information in Medicine, 22, 61 - 62.

A brief editorial note on the effective transfer of technology for use in health applications. The author's opinion is that the technology must fit in with the culture, ethos, infrastructure, manpower and human needs of a country at the lowest effective cost. A major consideration in computerisation is the need to generate indigenous support facilities. Another consideration is cost, which needs to be viewed from a long-term perspective of opportunity cost.

SHIRES, D.B., [1983], Health information systems applications in technologically lesser-developed countries: An overview, in: Fernandez Perez de Talens, A.F.P., Molino, E. & Shires, D. (eds.), Health informatics in developing countries: Experiences and viewpoints, North-Holland, 57 - 63.

This paper assesses the potential of health information systems for planning and resource management in developing countries. It describes some of the problems of implementing these systems, some possible solutions for successful implementation, and some anticipated future trends.

SHORTLIFFE, E.H., [1981], Consultation systems for physicians: The role of artificial intelligence techniques, in: Webber, B.L. & Nilsson, N.J. (eds.), Readings in artificial intelligence, Troga Publishing Company, 323 - 333.

Computers have hardly had an impact on the diagnostic decision-making practices of physicians. There are various reasons for this: the inexact nature of medical reasoning and what physicians expect when they consult a specialist for advice. Reliability is just one of seven issues the author lists as important in determining acceptability. He suggests some design criteria: mechanical (easy interaction); epistemological (quality of decisions, method of knowledge acquisition, instructional function, explanation facilities, knowledge representation techniques, automated knowledge acquisition); psychological (fit into the consultation process). MYCIN is described as an illustrative example.

SHORTLIFFE, E.H., [1987], Computer programs to support clinical decision making, Journal of the American Medical Association, 258:1, 61 - 66.

Excellent snapshot of the state-of-the-art. The article introduces the distinction between three types of clinical decision support tools: for information management, focusing attention, and patient-specific consultation. The last of these are dealt with in depth. The author proposes a list of issues that can affect successful implementation: system function, mode for giving advice, consultation style, underlying decision-science

methodology, and human factors. A review of the status of current systems follows, concluding with an assessment of the future research needs.

SHORTLIFFE, E.H., BUCHANAN, B.G. & FEIGENBAUM, E.A., [1984], Knowledge engineering for medical decision making: A review of computer- based clinical decision aids, in: Clancey, W.J. & Shortliffe, E.H. (eds.), Readings in medical artificial intelligence: The first decade, Addison Wesley, 35 - 71.

Excellent discussion of early knowledge representation techniques. Particularly interesting is the appraisal of clinical algorithms (or flowcharts) and their use as a manual or automated tool for paramedical workers; and Bayesian methods, to calculate the probability of a disease based on observations and data regarding frequency of the observations for specified diseases. Five other techniques are summarised, and all sections include a discussion of their history, an example of their use, and the problems of using that technique.

SHORTLIFFE, E.H. & CLANCEY, W.J., [1984], Anticipating the second decade, in: Clancey, W.J. & Shortliffe, E.H. (eds.), Readings in medical artificial intelligence: The first decade, Addison Wesley, 463 - 472.

Cautiously optimistic assessment of future research needs: what physicians want from systems, what problems have been solved so far, and the new challenges that have been uncovered. A very practical procedure for establishing a system's effectiveness is proposed. The chapter concludes with a statement of the expected future role of AIM.

SHORTLIFFE, E.H., PERREAULT, L.E., WEIDERHOLD, G. & FAGAN, L.M. (eds.), [1990], **Medical Informatics: Computer applications in health care**, Addison Wesley Publishing Company.

An extensive collection of review articles divided into three sections: recurrent themes in medical informatics, medical computing applications, and medical informatics in the years ahead. Chapter 15 is on clinical decision support and discusses their role, characteristics and difficulties in getting them operational. The chapter also includes examples of decision support systems and concludes with an assessment of their future roles.

SNOW, R.W. & BYASS, P., [1988], Computerised morbidity surveillance in the field, in: Proceedings of the African Population Conference, International Union for the Scientific Study of Population, Session 1.2, Dakar, Senegal, November 1988.

An example of the successful use of microcomputers for ongoing survey management. The paper describes the application context, and the organisation of the computer-based weekly surveillance system. The use of the system improved coverage rates, and enables errors and inconsistencies to be identified during the course of the study.

STEPHENS, J., ALONSO, P.L., BYASS, P. & SNOW, R.W., [1989], Tropical epidemiology: A system for continuous demographic monitoring of a study population, Methods of Information in Medicine, 28: 155 - 159.

In the same context as that described in Snow and Byass [1988], a database management system was set up to create an online continuous vital registration system for a study population. The advantages of the system are described.

STEVENSON, D. (ed.), [1987], Davey and Lightbody's The Control of Disease in the Tropics (5e), H.K. Lewis & Co. Ltd.

The introductory chapter is a discussion of the economic and social aspects of disease, emphasising that a general improvement in overall living standards and wealth will be the most important element in the decline of common communicable diseases. The other general chapters include definitions of terms used, and general measures of control. The bulk of the book deals with the control of specific diseases.

SUTTON, G.C., [1989], How accurate is computer-aided diagnosis?, The Lancet, October 14, 905 - 908.

Two computer programs on the diagnosis of acute abdominal pain were compared with clinical practice in some Scottish hospitals. Although he admits to some limitations in the generalisability of their results, the author concludes that the lower rate of accuracy in the computer-based systems suggests that no useful role exists for their use in this domain area.

SZOLOVITS, P., PATIL, R.S. & SCHWARTZ, W.B., [1988], Artificial intelligence in medical diagnosis, Annals of Internal Medicine, 108:1, 80 - 87.

The authors claim that useful programs for computer-aided diagnosis have still not emerged from research efforts, although many of the early problems impeding the development of effective systems have been solved. The paper concentrates on different methods of reasoning, in particular the use of deep pathophysiological methods and mechanisms for narrowing hypotheses. Newer problems have emerged though, and major breakthroughs will be necessary before expert performance by computer can be achieved.

THE COURIER, [1989], Dossier - Informatics and development, No 113, January - February 1989, 50 - 82.

An issue with a special dossier on informatics and development. It outlines the recent history of the computer, some of its advantages and drawbacks, and lists several examples of various computerisation projects. It discusses the recent dispersion of the technology around the third world and some of the national expansion policies that have been pursued. Several case studies of implementations are included.

TORO, V. & CHAMBERLAIN, K., [1989], Recent work with microcomputers for census processing in developing countries, Journal of Official Statistics, 5:1, 69 - 81.

Describes the growth of computerised census processing systems in many statistical offices of developing countries. A number of packages that have been developed for census management are discussed, as well as two case studies from Burkina Faso and Senegal. The paper outlines some of the challenges remaining for integrated microcomputer support.

UEMURA, K., [1983], Statistical components and requirements for health information systems, in: Fernandez Perez de Talens, A.F.P., Molino, E. & Shires, D. (eds.), Health informatics in developing countries: Experiences and viewpoints, North- Holland, 199 - 203.

The author defines the primary role of the health information system as to support the management of the national health system. It lists a number of common defects in the collection and processing of health statistics in developing countries. The optimum solution is for a drastic reduction in the amount of data collected to a bare minimum.

The paper also discusses related statistics and health indicators that should be collected.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION, [1986], The impact of expert systems, Regional and Country Studies Branch, Studies and Research Division.

The report examines trends and patterns of expert system use in industrialised countries, in an attempt to identify opportunities and problems for their use in developing countries. The document includes a survey of some existing applications from a range of domain areas, software and hardware trends, the main actors influencing the development of expert systems, some possible developments, and implications for developing country policies.

UPLEKAR, M.W., ANTIA, N.H. & DHUMALE, P.S., [1988], Sympmed I: Computer program for primary health care, British Medical Journal, 297, 841 - 843.

Describes SYMPMED I, an experimental computer program that offers therapeutic advice, based solely on patient symptom history. The description of software development is very scanty. The paper describes a preliminary evaluation of the system with a clinical and a non-clinical user, and presents some results based on comparing drug groups for the treatments described. It concludes by discussing some problems and limitations of the program, and its continued development.

VALLBONA, C., [1983], Information systems for health care in developing countries, in: Fernandez Perez de Talens, A.F.P., Molino, E. & Shires, D. (eds.), Health informatics in developing countries: Experiences and viewpoints, North-Holland, 87 - 100.

The difficulties in putting health information systems into operation in developing countries have been due to deficiencies in design, technological constraints, complexities of the health system, and human factors. A framework for the design and evaluation of systems for different levels of the health system, and from different perspectives is proposed.

WHITE, K.L., [1985], Health surveys: Who, why and what?, World Health Statistics Quarterly, 38, 2 - 14.

Health surveys are necessary to provide data for defining priorities, assessing decision-making options, evaluating policies and as a basis for comparison. The type of information needed to conduct a survey is listed, and some choices of survey methods outlined. The authors stress that there is a need to link various sources of information, and various kinds of surveys for maximum cost-effectiveness.

WILSON, R.G., ECHOLS, B.E., BRYANT, J.H. & ABRANTES, A. (eds.), [1988], Management information systems and microcomputers in primary health care, Aga Khan Foundation.

Proceedings of a workshop that addresses various aspects of introducing and managing health information systems. Some interesting articles include: issues and challenges of using microcomputers (an assessment of the current situation and some criteria for success); the impact information technology could have (considering some possible applications and planning factors for implementation); case studies from Uganda and Nepal; and guidelines on effective use of data.

WOFSEY, M.M. & DICKIE, P.M., [1971], Computers in less developed economies, Finance and Development, March 1971, 8, 2 - 6.

The authors discuss the arguments for and against the installation of computers in developing countries, outline some of the potential problems, and suggest eight questions that should be asked in justifying the use of computerisation.

WORKING GROUP 3, [1983], Medical informatics and the developing countries, in: Pages, J.C., Levy, A.H., Gremy, F. & Anderson, J. (eds.), Meeting the challenge: Informatics and medical education, Elsevier Science Publishers, 335 - 337.

Report of one of the working groups at this conference, concentrating on the application of medical informatics to areas of maximum importance in developing countries. It was noted that health systems vary too much for one particular strategy to be generally applicable; each situation must be assessed for strength and weaknesses. The group felt that decision support systems for rural health care professionals was a priority as well as training programmes, data management systems, use of modelling techniques in health care planning, and patient education. The need for eventual self-sufficiency in developing computer-based systems is stressed.

WORLD BANK, [1989], Sub-Saharan Africa: From crisis to sustainable growth, The World Bank, Washington, USA.

A report that overviews the last 30 years of African development. Addressing the theme of prospects for sustainable growth with equity, the report discusses the need for investing in people, agriculture, industry, entrepreneurship, and regional integration. It proposes a strategic agenda for the 1990s, suggesting ways that donors could co-operate in more effective development programmes.

WORLD BANK, [1990], World Development Report 1990 - Poverty, Oxford University Press.

This year's report focuses on the central theme of poverty. It defines poverty, and describes its distribution over the developing world. It seeks to find factors that contribute to national poverty, and then turns to considering poverty at the community level. It discusses the progress that has been and can be made to combat poverty, and how social services, economic incentives and buffers can be created for the poor. It addresses the need for international co-operation to combat the spread of poverty. Data is presented in the appendix on a range of development indicators, including population, basic health indicators and budgetary allocation.

WORLD HEALTH ORGANISATION, [1978], Primary Health Care. International Conference on Primary Health Care, Alma-Ata, USSR, September 1978.

The classic reference: the Health for All by Year 2000 strategy. The document stresses the need for essential community-based primary health care, with components that include nutrition, sanitation, maternal and child care, family planning, immunisation as well as treatment. The report discusses the relationship between health and development, and the operational aspects of putting the strategy into practice.

WORLD HEALTH ORGANISATION, [1987], How should information on health care be generated and used?, World Health Forum, 8:4, 409 - 438.

This booklet contains a series of round table discussion articles. The main article assesses the current methods of health data collection. Its main purpose should be to ultimately serve a population, but often a bureaucratic top-down approach is instituted

instead, producing much unused data. The author proposes a bottom-up approach driven by community needs, with a decentralised structure. The other papers discuss the issues raised in the first article.

WORLD HEALTH ORGANISATION, [1988], Informatics and telematics in health: Present and potential uses, WHO, Geneva.

A rather boring approach to considering the possible applications of information technology in health, making the report rather repetitious in structure and content. It covers health informatics policy and strategy, informatics support for health programmes (management, stock control, administration), informatics support in the provision of health care (community, primary and hospital care, medical records, decision support, statistics, literature and knowledge bases), informatics for health manpower development, and the choice of informatics technology.

WYATT, J. & SPIEGELHALTER, D., [1990], Evaluating medical expert systems: what to test and how?, Medical Informatics, 15, 205 - 217.

Few medical expert systems have been evaluated despite the belief of some researchers in their potential. The authors discuss their proposal for evaluating medical expert systems in two stages: laboratory and field testing. In the first stage, the user and expert perspectives are important, and specific questions can be asked about the structure, process and outcome of the system's reasoning from these perspectives. During the field trial stage, certain biases must be controlled for in the design, and questions must concern the possible effects on the structure, process and outcome of health care.

XINSONG, J., GUONING, S. & YU, C., [1983], AI research in China: A review, **MEDINFO '83**, 164 - 166.

A short unwieldly article, which makes some mention of medical expert systems research in China. It includes sketchy overviews of a few medical expert consulting systems.

ZEDAP, MINISTRY OF HEALTH, ZIMBABWE, [1987], Acute medical conditions.

A manual for paramedical workers covering a range of conditions that can be treated at the primary care level. It is organised by main presenting symptoms, and well illustrated. All conditions are defined, with causes, common symptomatic indications, signs and management options listed.

ZIMMERMAN, J.B., [1984], Politiques africaines de l'informatique, Politique Africaine, March 1984, No 13, 79 - 90.

The author describes some of the characteristics of computerisation in developing countries: the historical development of centralised processing, and the domination of multinational firms. The paper lists the dates of implementation of various computerised applications in some African countries. It discusses the need for informatics policies and regional integration.

ZWANGOBANI, E., [1990], Information technology in Africa: An overview, in: Bhatnagar, S.C. & Bjorn-Andersen, N. (eds.), Information technology in developing countries, North-Holland, 167 - 173.

This paper argues that a distinction should be made between national policies and policies for the government sector. It lists the two main obstacles to information technology implementation as the lack of foreign exchange and the shortage of manpower. Several issues that need to be considered in designing policies are also discussed.

APPENDIX B

LIST OF CONTACTS

This list was compiled from a variety of sources, but primarily from correspondence addresses listed on the articles referred to. This was supplemented by personal contacts, and the IDRC list of project holders. About a quarter of these contacts have either [*D] or [*C] against their name. Those who have been met in person for discussion are marked [*D], and those from whom correpondence has been received are marked [*C].

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